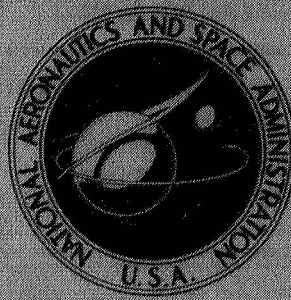


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MEMORANDUM



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EXPERIMENTAL AERODYNAMIC CHARACTERISTICS  
FOR A CYLINDRICAL BODY OF REVOLUTION  
WITH SIDE STRAKES AND VARIOUS NOSES  
AT ANGLES OF ATTACK FROM  $0^\circ$  TO  $58^\circ$   
AND MACH NUMBERS FROM 0.6 TO 2.0

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16. Abstract  <p>For a body of revolution with afterbody side strakes, an experimental investigation was conducted in the Ames 6- by 6-Foot Wind Tunnel to determine the effects on the aerodynamic characteristics of forebody geometry, nose strakes, body side strakes, Reynolds number, Mach number, and angle of attack. Aerodynamic force and moment characteristics were measured for the straked cylindrical afterbody (cylinder fineness ratio of 7) with tangent ogive noses of fineness ratio 2.5 to 5.0. In addition, the straked cylinder afterbody was tested with an ogive nose having a rounded tip and an ogive nose with two different nose strake arrangements.</p> <p>The various configurations were tested at Mach numbers of 0.6, 0.9, 1.2, 1.5, and 2.0 at angles of attack from 0° to 58°. The Reynolds numbers, based on body base diameter, were <math>2.2 \times 10^5</math>, <math>4.3 \times 10^5</math>, and <math>6.5 \times 10^5</math> at <math>M = 0.6</math> and 0.9 and <math>3.8 \times 10^5</math> at <math>M = 1.2, 1.5</math>, and 2.0.</p> <p>The data demonstrate that the aerodynamic characteristics for a body of revolution with side strakes can be significantly affected by changes in nose fineness ratio, nose bluntness, Reynolds number, Mach number, and, of course, angle of attack. Removing the strakes from the cylindrical aftersection greatly decreased the lift, but this removal hardly changed the maximum magnitudes of the undesirable side forces that developed at angles of attack greater than about 25° for subsonic Mach numbers.</p>					
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## NOMENCLATURE

All forces and moments are referred to the body axis coordinate system. Because the data are computer plotted, both the conventional symbol and the plot symbol are given.

<u>Symbol</u>	<u>Plot Symbol</u>	<u>Definition</u>
$A_r$		reference area = body base area = 34.26 cm <sup>2</sup> (5.31 in. <sup>2</sup> )
$C_A$	CA	axial-force coefficient, $C_{A_{bal}} - C_{A_{base}}$
$C_{A_{bal}}$		balance axial-force coefficient, $\frac{F_A}{qA_r}$
$C_{A_{base}}$		base-pressure force coefficient, $\frac{(p - p_{base})}{q}$
$C_m$		pitching-moment coefficient about balance center 4d from body base, $\frac{\text{pitching moment}}{qA_r X}$
$C_N$	CN	normal-force coefficient, $\frac{F_N}{qA_r}$
$C_n$	CYN	yawing-moment coefficient about balance center 4d from body base, $\frac{\text{yawing moment}}{qA_r X}$
$C_Y$	CY	side-force coefficient, $\frac{F_Y}{qA_r}$
$d$		body base diameter = 6.60 cm (2.60 in.)
$F_A, F_N, F_Y$		axial, normal, and side force, respectively
$\ell_N$		nose length
$M$	MACH	free-stream Mach number
$p$		free-stream static pressure
$p_{base}$		base pressure

$q$		free-stream dynamic pressure
$\frac{Re}{L}$		unit Reynolds number, million/m
$Re$	RE	Reynolds number based on $d$
$X$		reference length = $d = 6.60$ m (2.60 in.)
$\frac{x_{acN}}{d}$	XACN/D	distance (in diameters) from body base to aerodynamic force center in normal-force plane, $\left(\frac{C_m}{C_N} + \frac{x_m}{X}\right)$
$x_m$		distance from body base to balance moment reference = $4d = 26.42$ cm (10.40 in.)
$\alpha$	ALPHA	angle of attack, deg

#### Configuration Code

<u>Symbol</u>	<u>Plot Symbol</u>	<u>Component</u>	<u>Fineness Ratio</u>
$C_1$	C1	circular cylinder	7
$N_1$	N1	tangent ogive nose	3
$N_2$	N2	tangent ogive nose	3.5
$N_3$	N3	tangent ogive nose	5
$N_4$	N4	tangent ogive nose with rounded tip	3
$N_5$	N5	tangent ogive nose with tip strakes	3
$N_6$	N6	tangent ogive nose with side strakes	3
$N_7$	N7	tangent ogive nose	2.5
$S$	S	side strakes on circular cylinder	



**EXPERIMENTAL AERODYNAMIC CHARACTERISTICS FOR A CYLINDRICAL BODY  
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OF ATTACK FROM 0° TO 58° AND MACH NUMBERS FROM 0.6 TO 2.0**

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**SUMMARY**

For a body of revolution with afterbody side strakes, an experimental investigation was conducted in the Ames 6-by 6-Foot Wind Tunnel to determine the effects on the aerodynamic characteristics of forebody geometry, nose strakes, body side strakes, Reynolds number, Mach number, and angle of attack. Aerodynamic force and moment characteristics were measured for the straked cylindrical afterbody (cylinder fineness ratio of 7) with tangent ogive noses of fineness ratio 2.5 to 5.0. In addition, the straked cylinder afterbody was tested with an ogive nose having a rounded tip and an ogive nose with two different nose strike arrangements.

The various configurations were tested at Mach numbers of 0.6, 0.9, 1.2, 1.5, and 2.0 at angles of attack from 0° to 58°. The Reynolds numbers, based on body base diameter, were  $2.2 \times 10^5$ ,  $4.3 \times 10^5$ , and  $6.5 \times 10^5$  at  $M = 0.6$  and  $0.9$  and  $3.8 \times 10^5$  at  $M = 1.2$ ,  $1.5$ , and  $2.0$ .

The data demonstrate that the aerodynamic characteristics for a body of revolution with side strakes can be significantly affected by changes in nose fineness ratio, nose bluntness, Reynolds number, Mach number, and, of course, angle of attack. Removing the strakes from the cylindrical aftersection greatly decreased the lift, but this removal hardly changed the maximum magnitudes of the undesirable side forces that developed at angles of attack greater than about 25° for subsonic Mach numbers.

**INTRODUCTION**

High angle-of-attack aerodynamics is increasing in importance because of the demand for greater maneuverability of missiles and aircraft (both manned and remotely piloted). Some recent introductory investigations in this field are reported in references 1 to 9. Presently, however, there is great need to enlarge the relatively small data base for basic bodies alone and in combination with strakes, wings, and tails at subsonic, transonic, and supersonic Mach numbers.

To help fill this need, an investigation has been conducted to measure the aerodynamic force and moment characteristics for a cylindrical body of revolution (cylinder fineness ratio of 7) with side strakes and with tangent ogive noses of fineness ratio 2.5 to 5.0. In addition, the cylindrical

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body with strakes has been tested with an ogive nose having a rounded tip and an ogive nose with two different strake arrangements. In reference 8, similar tests were made with no strakes mounted on the cylindrical body.

In both investigations, the cylindrical body was tested with the various noses in the Ames 6- by 6-Foot Wind Tunnel at Mach numbers of 0.6, 0.9, 1.2, 1.5, and 2.0. The Reynolds numbers, based on model base diameter, were  $2.2 \times 10^5$ ,  $4.3 \times 10^5$ , and  $6.5 \times 10^5$  at the subsonic Mach numbers and  $3.8 \times 10^5$  at the supersonic Mach numbers. Six-component static aerodynamic force and moment coefficients were measured for angles of attack from  $0^\circ$  to  $58^\circ$ .

This report presents the basic data that show the effects on the aerodynamic characteristics of nose fineness ratio, nose tip rounding, nose strakes, Reynolds number, and Mach number over the angle-of-attack range. In addition, the effect of removing the strakes from the cylindrical afterbody is illustrated with the aid of comparative data from reference 8 for the body without strakes.

## TEST FACILITY

The experimental investigation was conducted in the Ames 6- by 6-Foot Wind Tunnel – a variable pressure, continuous flow, closed-return type facility. The nozzle ahead of the test section consists of an asymmetric sliding block that permits the Mach number to be continuously varied from 0.6 to 2.3. The test section has a perforated floor and ceiling so that the boundary layer can be removed for transonic testing.

## MODELS AND BALANCE

Figure 1 shows the model components. All models tested consisted of a combination of one of the seven noses with the circular-cylinder aftersection. The cylinder aftersection ( $C_1$ ) was 7 diameters long and had small side strakes ( $S$ ) extending along the entire length. Noses  $N_1$ ,  $N_2$ ,  $N_3$ , and  $N_7$  were all circular-arc tangent ogives from 2.5 to 5 diameters long. Noses  $N_4$ ,  $N_5$ , and  $N_6$  were also circular-arc tangent ogives but with some modifications.  $N_4$  was formed by rounding the tip of a fineness-ratio 3.5 ogive to give a resulting fineness ratio of 3.  $N_5$  was a fineness-ratio-3 ogive with side strakes near the tip, and  $N_6$  was a similar ogive but with side strakes extending over the entire nose length.

All model parts were constructed of stainless steel, and the models were sting mounted through the base on a six-component, strain-gage "Task" balance. The balance force center was located inside the cylindrical body 4 diameters forward of the base.

Figure 2 shows planform views of the configurations tested. The planform views of the same configurations without side strakes along the cylinder are also shown for comparison. Results for these configurations are reported in reference 8. All configurations tested are identified by the code shown in figure 2.

## TESTS AND DATA REDUCTION

All configuration arrangements shown in figure 2 were tested at  $\alpha = 0^\circ$  to about  $58^\circ$ . Two model support setups were used — one for  $\alpha = 0^\circ$  to about  $27^\circ$  and the other for  $\alpha = 27^\circ$  to  $58^\circ$ . Photographs of these setups are shown in reference 8. The models were tested at the following Mach numbers and Reynolds numbers:

<u>M</u>	<u>Re <math>\times 10^{-6}</math> (m)</u>	<u>Re <math>\times 10^{-6}</math> (ft)</u>	<u>Re <math>\times 10^{-5}</math> (based on d)</u>
0.6, 0.9	3.28	1.0	2.2
0.6, 0.9	6.56	2.0	4.3
0.6, 0.9	9.84	3.0	6.5
1.2, 1.5, 2.0	5.74	1.75	3.8

Six-component aerodynamic force and moment data were measured at each test condition, and all data were reduced to coefficient form and referred to the body axis coordinate system. The average base pressure from four base pressure tubes (at the sides, top, and bottom of the base) was used to compute the base drag, which was subtracted from the total axial-force balance measurements, so that the data presented are for forces ahead of the body base. Rolling-moment coefficients were generally negligible and are omitted. Normal-force aerodynamic centers were computed from the normal-force and pitching-moment coefficients and are presented in lieu of the pitching-moment coefficients.

## RESULTS AND DISCUSSION

Experimental results (figs. 3–27) show the effects on the aerodynamic characteristics of nose fineness ratio, nose tip rounding, nose strakes, removal of strakes from the cylindrical afterbody, Reynolds number, and Mach number. Each effect is discussed briefly with the aid of plots of  $C_N$ ,  $x_{acN}/d$ ,  $C_Y$ ,  $C_Y/C_N$ , and  $C_n$  versus  $\alpha$  for  $\alpha = 0^\circ$  to  $60^\circ$ . Plots of  $C_A$  versus  $\alpha$  are also presented but are not discussed. Because the models were sting supported from the rear, it is likely that the  $C_A$  data include effects of support interference.

### Effect of Nose Fineness Ratio

Data that show the effect of nose fineness ratio on the aerodynamic characteristics are presented in figures 3 through 7 for  $M = 0.6$  to 2.0. The data are for the highest test Reynolds numbers —  $Re = 6.5 \times 10^5$  at  $M = 0.6$  and 0.9 (figs. 3 and 4) and  $Re = 3.8 \times 10^5$  at  $M = 1.2$ , 1.5, and 2.0 (figs. 5–7). Comparisons are made for the cylinder ( $C_1$ ) with side strakes ( $S$ ) and noses ( $N_1$ ,  $N_2$ ,  $N_3$ , and  $N_7$ ) of fineness ratio 3, 3.5, 5, and 2.5, respectively.

An increase in the nose fineness ratio from 2.5 to 5.0 can change the aerodynamic characteristics significantly. As expected, normal-force coefficient generally increases with increase in nose fineness ratio at all Mach numbers, and the aerodynamic force center in the normal-force plane

moves forward. However, at some angles of attack, the changes are negligible, especially at subsonic Mach numbers.

Probably the most interesting result is the effect of nose fineness ratio on the development of side force and yawing moment with an increase in  $\alpha$  above about  $25^\circ$ . At  $M = 0.6$  and  $0.9$  (figs. 3 and 4), the side-force and yawing-moment coefficients become rather large for the straked cylinder with the fineness ratio 3.5 and 5.0 noses (configurations  $N_2C_1S$  and  $N_3C_1S$ ). In fact, for some angles of attack, the side forces become as large as about 30 percent of the normal forces (see plots of  $C_Y/C_N$  vs.  $\alpha$ ). When the nose fineness ratio is 3.0 or less (configurations  $N_1C_1S$  and  $N_7C_1S$ ), the side-force and yawing-moment coefficients become essentially zero throughout the  $\alpha$  range. In reference 8, similar results are shown for these configurations without the side strakes on the cylindrical afterbody. This side-force phenomenon appears to be associated primarily with subsonic flow. The side-force and yawing-moment coefficients are small at  $M = 1.2$  (fig. 5) and completely disappear at  $M = 1.5$  (fig. 6) and  $M = 2.0$  (fig. 7).

Based on the results from this investigation and from other studies (e.g., refs. 1, 2, 7-9), two conclusions are evident. First, the magnitudes of the maximum side-force and yawing-moment coefficients generally increase with an increase in the nose fineness ratio. Second, the magnitudes appear to decrease with an increase in Mach number up to about  $M = 1.2$ .

#### Effect of Nose Tip Rounding

In figures 8 through 12, data are presented for the straked cylinder ( $C_1S$ ) with the fineness ratio 3.5 ogive nose ( $N_2$ ) and with the fineness ratio 3.5 ogive nose whose tip was cut back by rounding to give a nose fineness ratio of 3 ( $N_4$ ). Data for the straked cylinder ( $C_1S$ ) combined with the fineness ratio 3 sharp ogive nose ( $N_1$ ) are also shown for comparison.

The effect of nose tip rounding on the variation of  $C_N$  and  $x_{acN}/d$  with  $\alpha$  is generally small at all Mach numbers investigated. The tip rounding is beneficial, however, in decreasing the side-force and yawing moment coefficients that appear at  $M = 0.6$  and  $0.9$  for  $\alpha > 25^\circ$ . At  $M = 0.6$  (fig. 8), the initial development of side force is at a higher  $\alpha$  for the blunt nose than for the sharp (cf.  $C_Y$  vs.  $\alpha$  results for  $N_4C_1S$  and  $N_2C_1S$ ).

Although nose blunting by rounding the tip appears beneficial in reducing side force, decreasing the nose fineness ratio can be even more beneficial in this case. As shown in figures 8 and 9, the side-force and yawing-moment coefficients are smaller for the configuration ( $N_1C_1S$ ) with the sharp-nosed ogive of fineness ratio 3 than for the configuration ( $N_4C_1S$ ) with the blunted nose of the same resulting fineness ratio. A similar result is reported in reference 8 for these configurations without the cylinder side strakes.

#### Effect of Nose Strakes

In figures 13 through 17, data are presented that show the effect of nose strakes on the aerodynamic characteristics. Data are compared for the straked cylinder ( $C_1S$ ) combined with the fineness ratio 3 ogive nose ( $N_1$ ) and the straked cylinder combined with the fineness ratio 3 noses with tip and side strakes ( $N_5$  and  $N_6$ ).



As expected, the nose strakes provide some additional normal force and move the aerodynamic force centers forward. The configuration with the nose strakes extending over the nose length ( $N_6C_1S$ ) appears to resist the development of side force and yawing moment best at the high angles of attack (see fig. 13). However, for all configurations compared, the side-force and yawing-moment coefficients are small at  $M = 0.6$  and essentially zero at the higher Mach numbers. Unfortunately, the nose strakes were not investigated for the body with the fineness ratio 5 nose, the nose that developed the largest side forces.

#### Effect of Removing Strakes From Cylindrical Afterbody

In figures 18 through 22, data are presented that show the effect on the aerodynamic characteristics of removing the strakes from the sides of the cylindrical afterbody. Results for the straked cylinder with the fineness ratio 5 nose (configuration  $N_3C_1S$ ) are compared with results for the same configuration without the strakes ( $N_3C_1$ ). Also, results for the straked cylinder with the fineness ratio 3 nose with tip strakes ( $N_5C_1S$ ) are compared with results for this configuration without the cylinder strakes ( $N_5C_1$ ).

As expected, removing the side strakes greatly reduces the normal force and moves the aerodynamic force center forward at all test conditions. Removing the strakes might also be expected to increase the magnitudes of the undesirable side forces and yawing moments that develop at high angles of attack. However, as shown in figure 18 for  $M = 0.6$ , removing the strakes from configurations  $N_3C_1S$  and  $N_5C_1S$  resulted in only little change in the maximum magnitudes of  $C_Y$  (CY) and  $C_N$  (CYN), although the variations of  $C_Y$  with  $\alpha$  were changed. It thus appears that controlling undesirable side forces and yawing moments at high  $\alpha$  might best be accomplished by changing the nose shape (probably by blunting the nose or reducing the fineness ratio as previously discussed).

#### Effect of Reynolds Number

In figures 23 through 26, the data presented show the effect of Reynolds number for configurations  $N_1C_1S$  and  $N_3C_1S$ . The Reynolds numbers are  $2.2 \times 10^5$ ,  $4.3 \times 10^5$ , and  $6.5 \times 10^5$  based on body base diameter.

For both configurations, there is no significant effect of Reynolds number on the variation of  $C_N$  and  $x_{acN}/d$  with  $\alpha$  at any of the Mach numbers considered. This result is in opposition to the result reported in reference 8 for the same bodies without side strakes at  $M = 0.6$ . In reference 8, the same increase in Reynolds number from  $2.2 \times 10^5$  to  $6.5 \times 10^5$  was accompanied by a decrease in  $C_N$  at the higher values of  $\alpha$ . Apparently, the crossflow for a body without side strakes is more sensitive to Reynolds number than the crossflow for a body with side strakes.

As for the bodies without side strakes, the effect of Reynolds number on side-force and yawing-moment coefficients appears to be significant only for the configuration ( $N_3C_1S$ ) with the high fineness ratio nose ( $\ell_N/d = 5$ ) at  $M = 0.6$  (fig. 25). The values of side force relative to normal force ( $C_Y/C_N$ ) generally decrease with increase in Reynolds number, but there is little effect on the variation of  $C_N$  with  $\alpha$ .

## Effect of Mach Number

In figure 27, the data presented show the effect of Mach number on the aerodynamic characteristics for configuration  $N_3 C_1 S$  (the fineness ratio 5 ogive nose attached to the straked cylinder). For  $M = 0.6$  and  $0.9$ , the Reynolds number is  $6.5 \times 10^5$ , and for  $M = 1.2, 1.5$ , and  $2.0$ , the Reynolds number is  $3.8 \times 10^5$ .

The plots of  $C_Y$  (CY) and  $C_n$  (CYN) as a function of  $\alpha$  clearly demonstrate that the side forces, which develop above  $\alpha \approx 25^\circ$ , are largest at the lowest Mach number,  $M = 0.6$ . The side forces diminish considerably with an increase in Mach number to  $M = 1.2$  and disappear at the higher supersonic Mach numbers.

At the subsonic Mach numbers, the side forces become as large as 25 percent of the normal forces. Similar results are reported in reference 8 for the same configuration without the side strakes.

## CONCLUSIONS

1. An increase in nose fineness ratio caused significant changes in the aerodynamic characteristics. Normal-force coefficient generally increased, and the aerodynamic normal-force center moved forward. For noses of fineness ratio greater than 3, large side-force and yawing-moment coefficients developed at subsonic Mach numbers for angles of attack above about  $25^\circ$ .

2. The large side-force and yawing-moment coefficients that developed at subsonic Mach numbers greatly decreased with increase in Mach number to  $M = 1.2$  and disappeared at  $M = 1.5$  and  $2.0$ .

3. Nose-tip rounding of a fineness ratio 3.5 ogive nose decreased the side-force and yawing-moment coefficients for the straked body at subsonic Mach numbers. However, the beneficial decrease was not as large as that obtained by merely using a sharp-nosed ogive of the same fineness ratio (fineness ratio 3) as that for the resulting blunted nose.

4. Nose strakes provided some additional normal force and moved the aerodynamic force centers forward. They provided little or no changes to the side forces and yawing moments for the body with the fineness ratio 3 nose. (Unfortunately, they were not investigated for the body with the fineness ratio 5 nose, the nose that developed the largest side forces.)

5. Removing the strakes from the sides of the cylindrical afterbody resulted in little change in the maximum magnitudes of the undesirable side forces and yawing moments that developed at  $\alpha$  greater than about  $25^\circ$ . The distribution of  $C_Y$  with  $\alpha$ , however, was considerably changed.

6. Reynolds number change from  $2.2 \times 10^5$  to  $6.5 \times 10^5$  had no significant effect on the variation of normal-force coefficient and aerodynamic center with angle of attack. The effect of

Reynolds number on the side-force and yawing-moment coefficients was significant only for the configuration with the fineness ratio 5 nose at the lowest Mach number,  $M = 0.6$ .

Ames Research Center  
National Aeronautics and Space Administration  
Moffett Field, California, September 26, 1974

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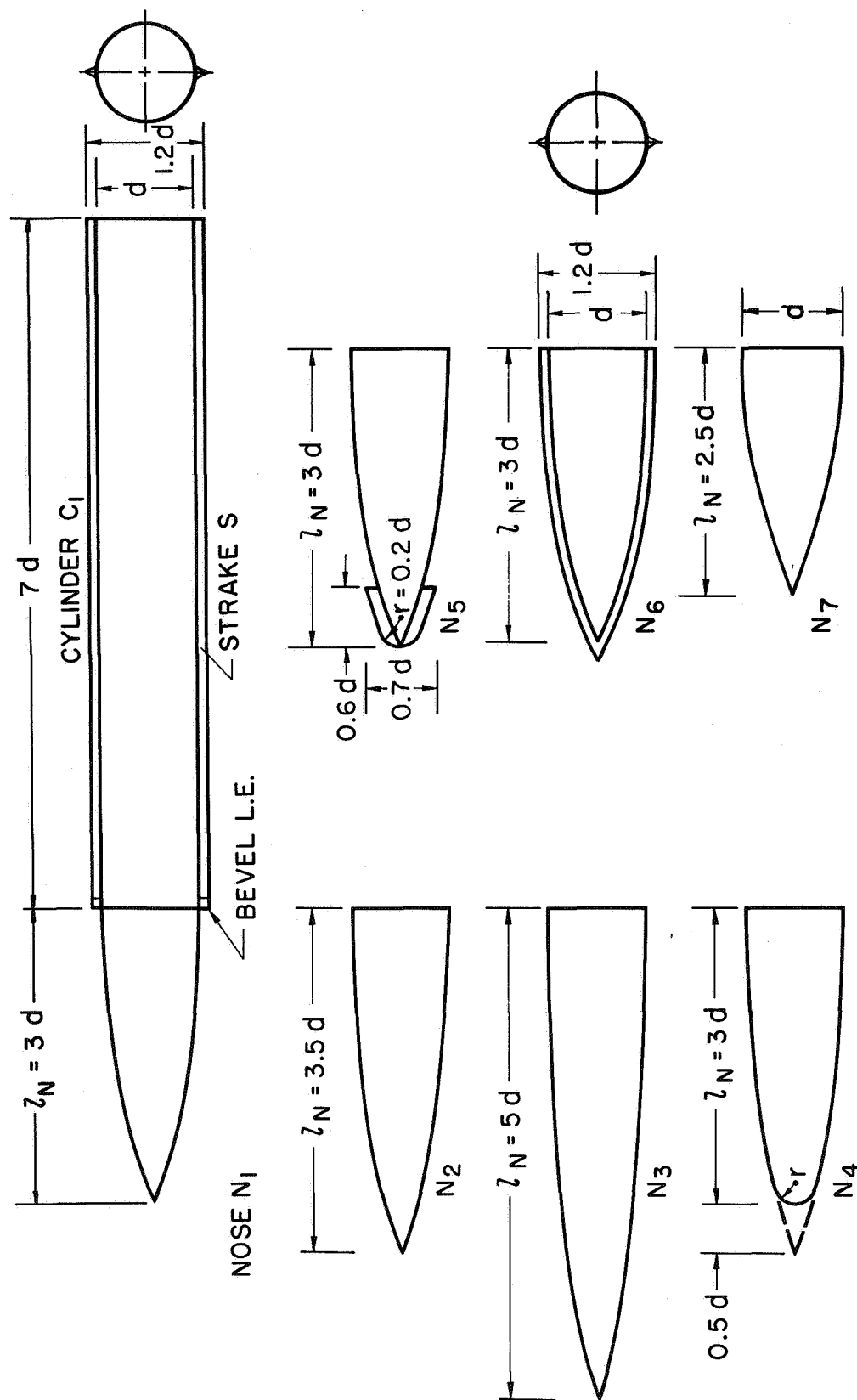
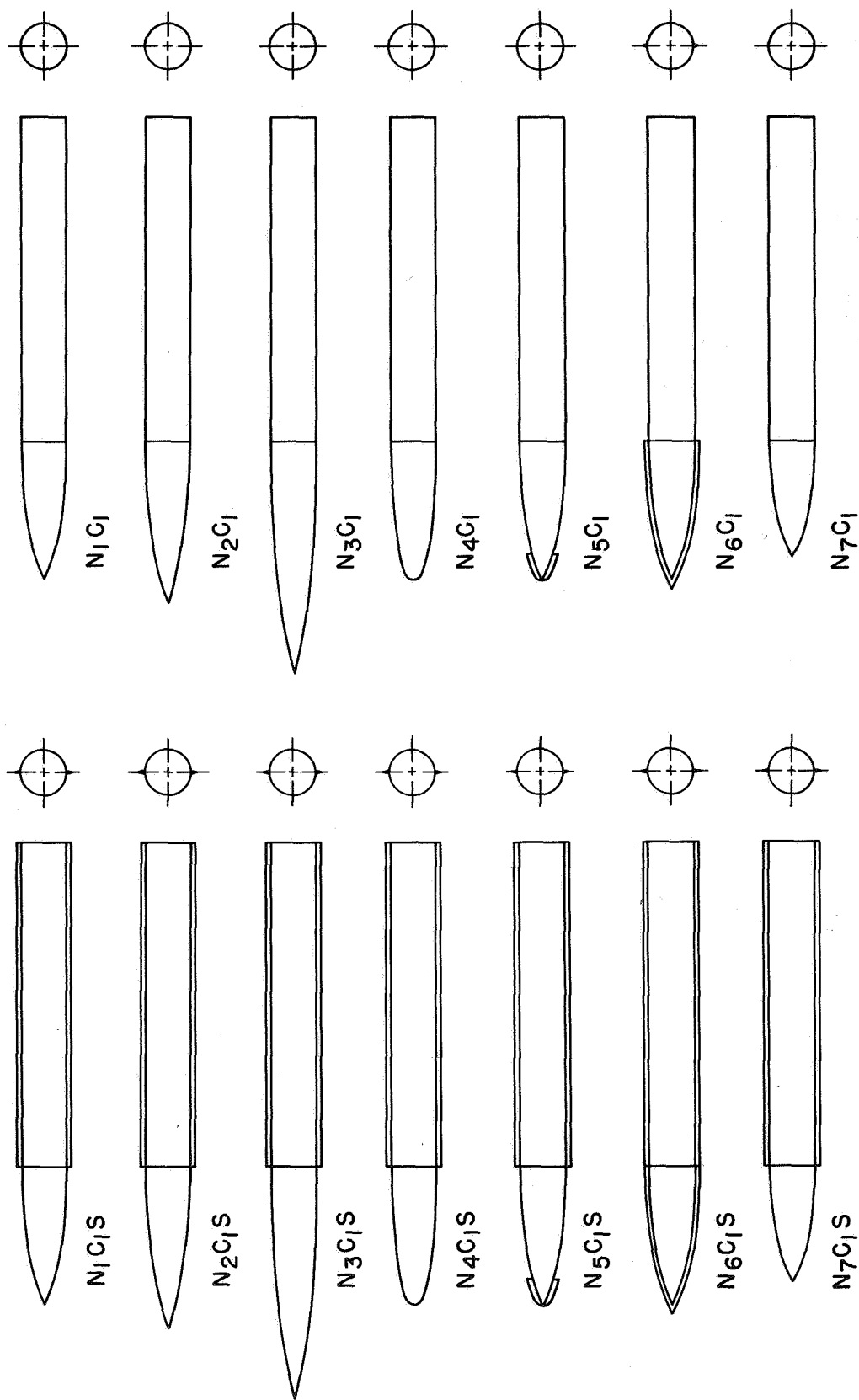


Figure 1.— Model components,  $d = 6.6$  cm (2.60 in.).

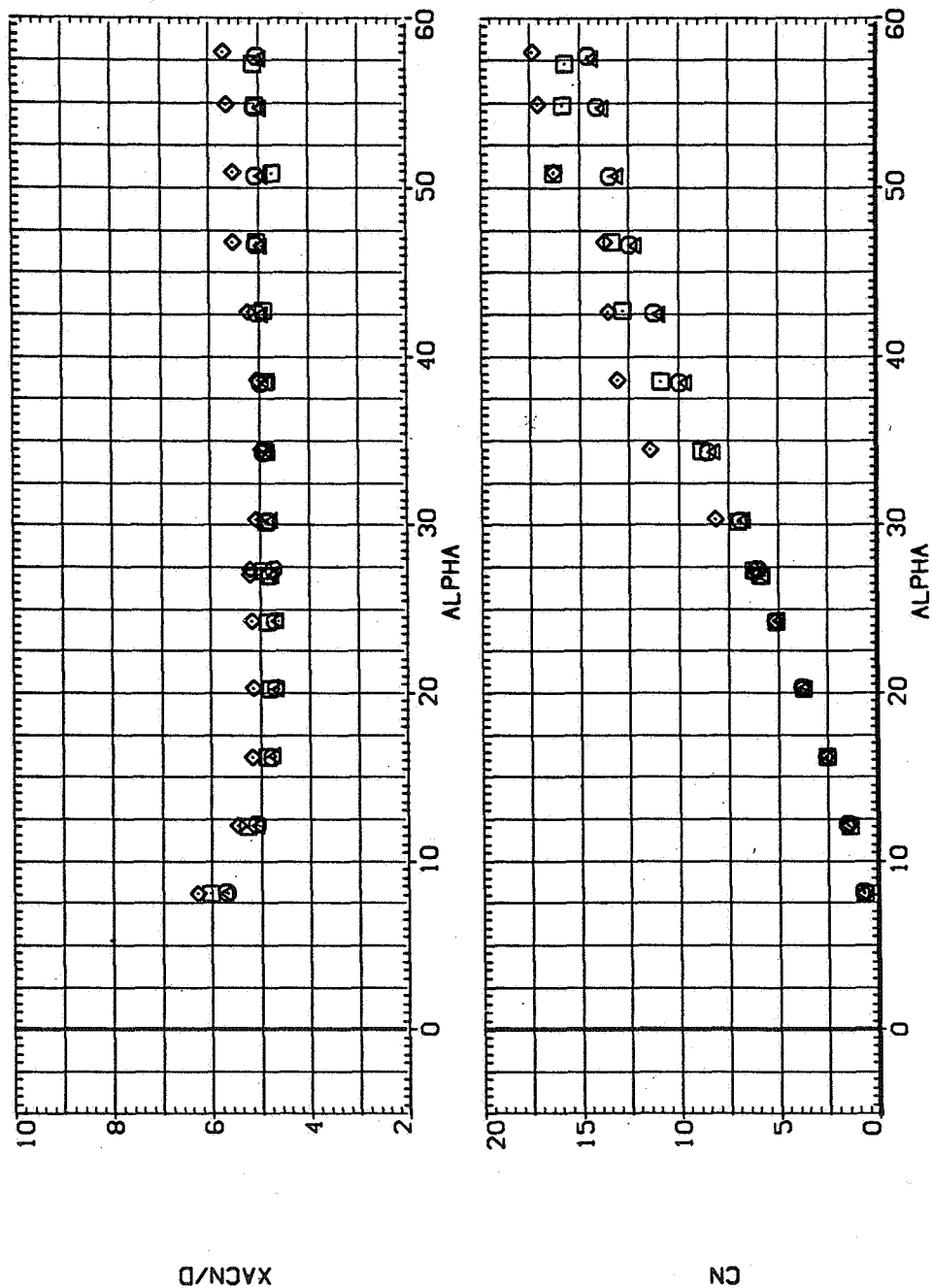


(a) Configurations for present report.

(b) Configurations for reference 8.

Figure 2.— Planform views of configurations tested.

SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N3 C1 S  
 N7 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 3.— Effect of nose fineness ratio;  $M = 0.6$ ,  $Re = 6.5 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1 C1 S1 S1 S  
 $\square$  N2 C1 S1 S1 S  
 $\square$  N3 C1 S1 S1 S  
 $\square$  N7 C1 S1 S

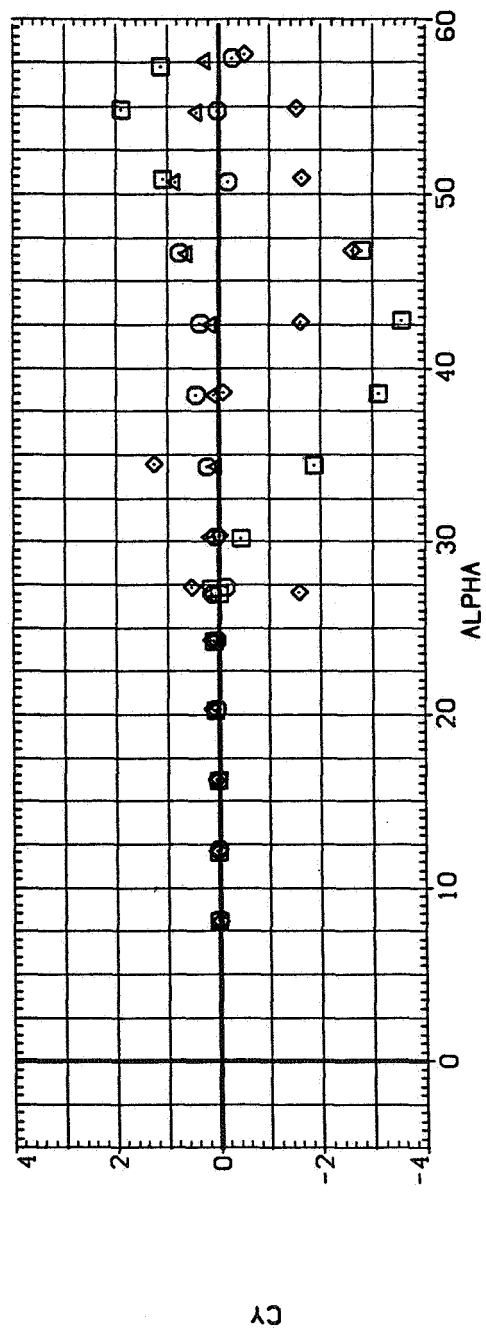
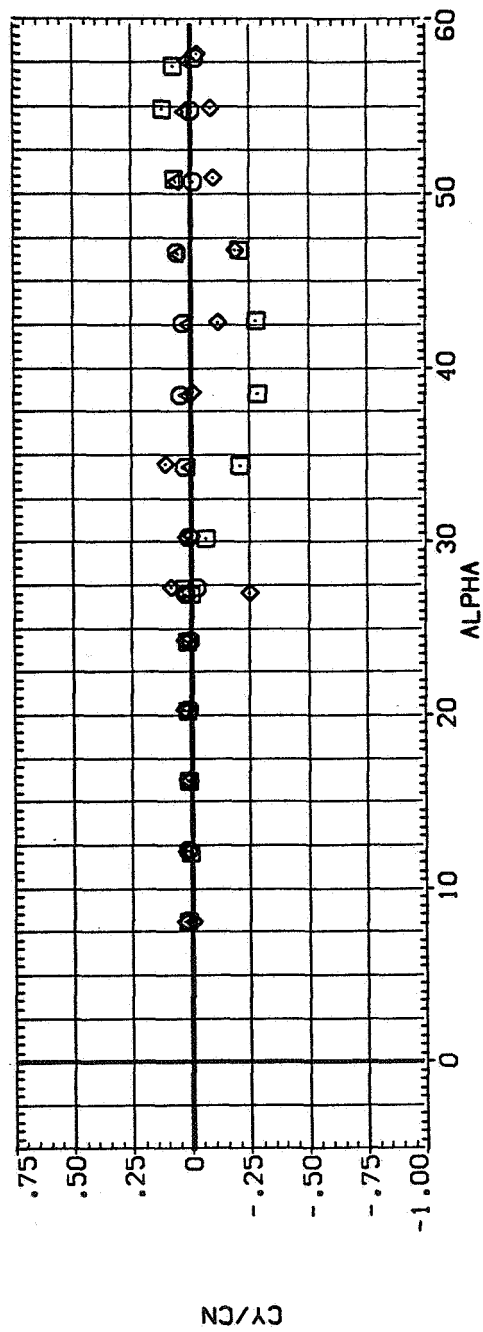
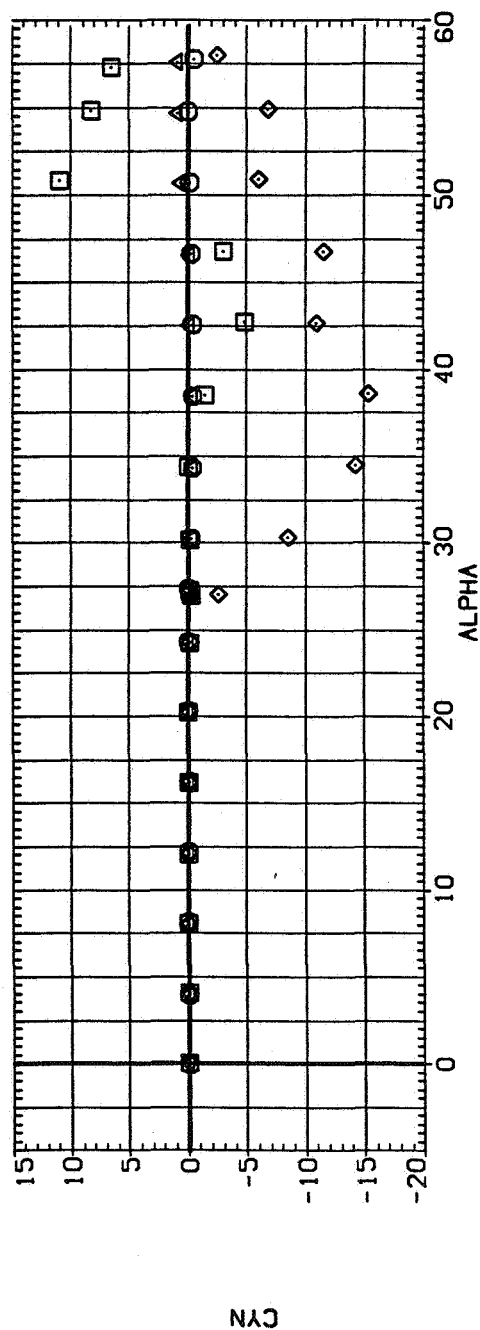
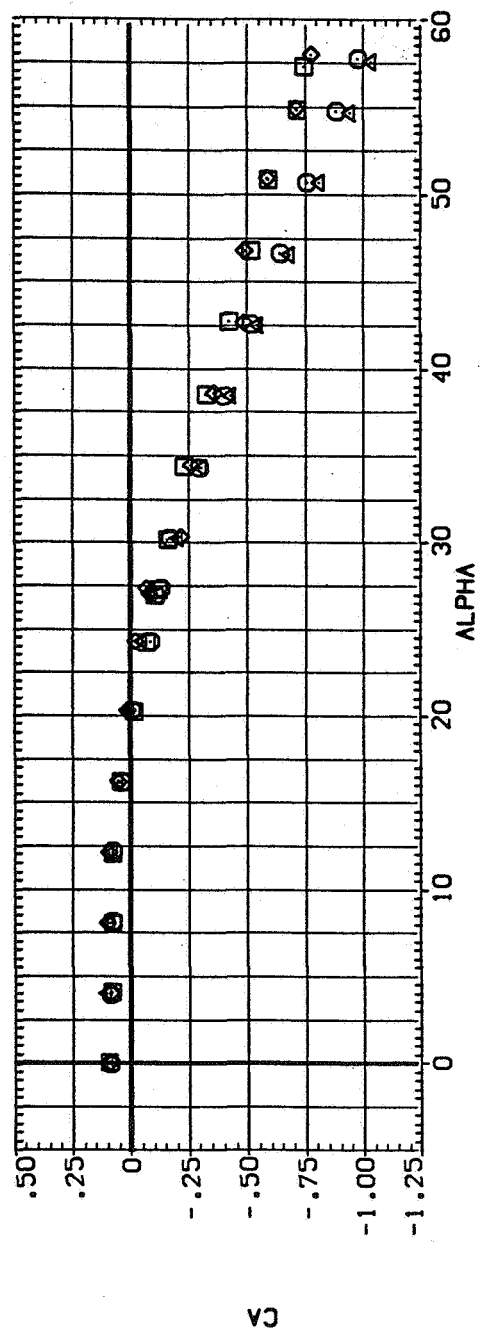
(b)  $CY/CN$  and  $CY$  versus  $\alpha$ .

Figure 3.— Continued.



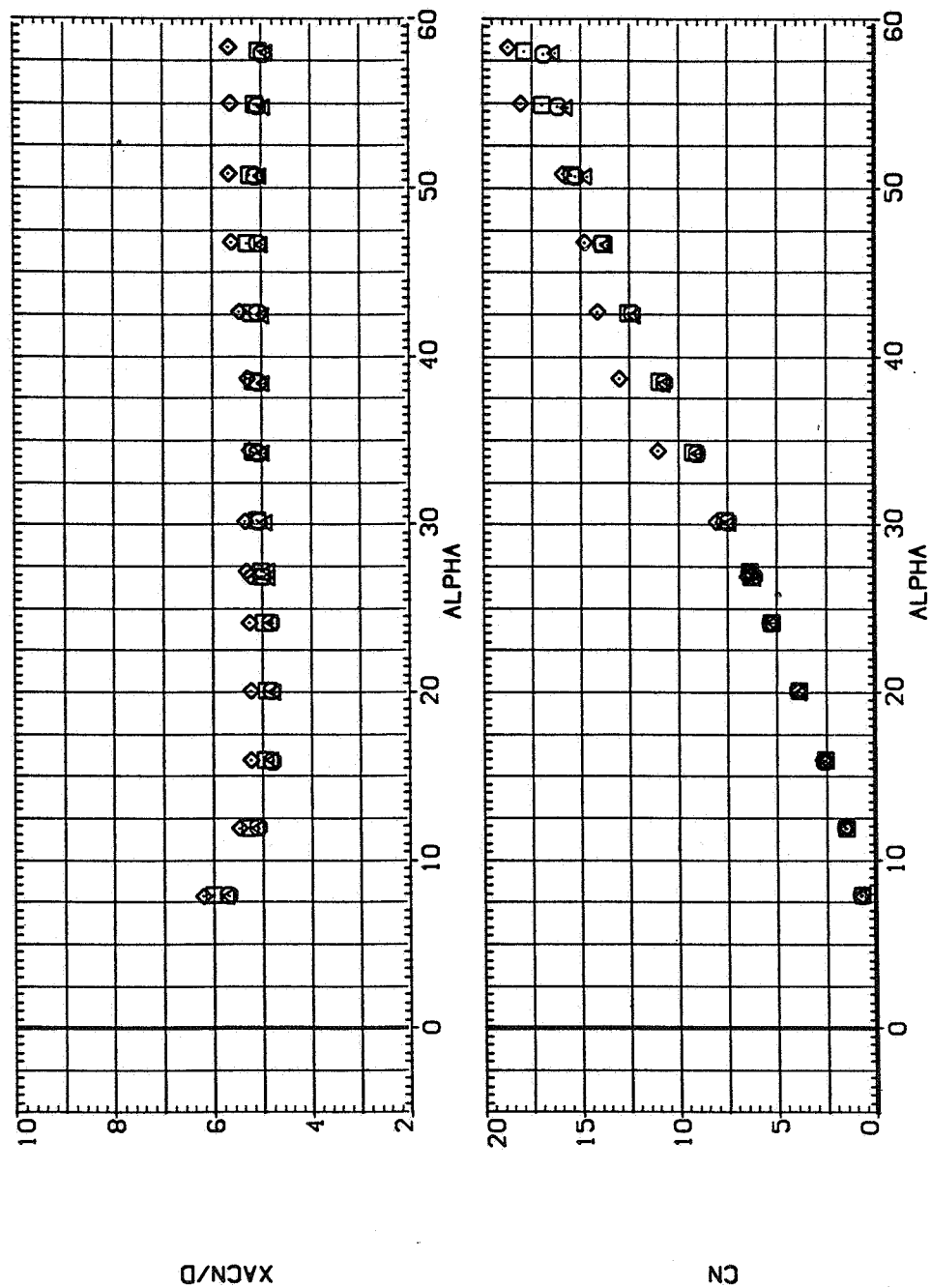
SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NI CI S  
 NI CI S  
 NI CI S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 3.— Concluded.

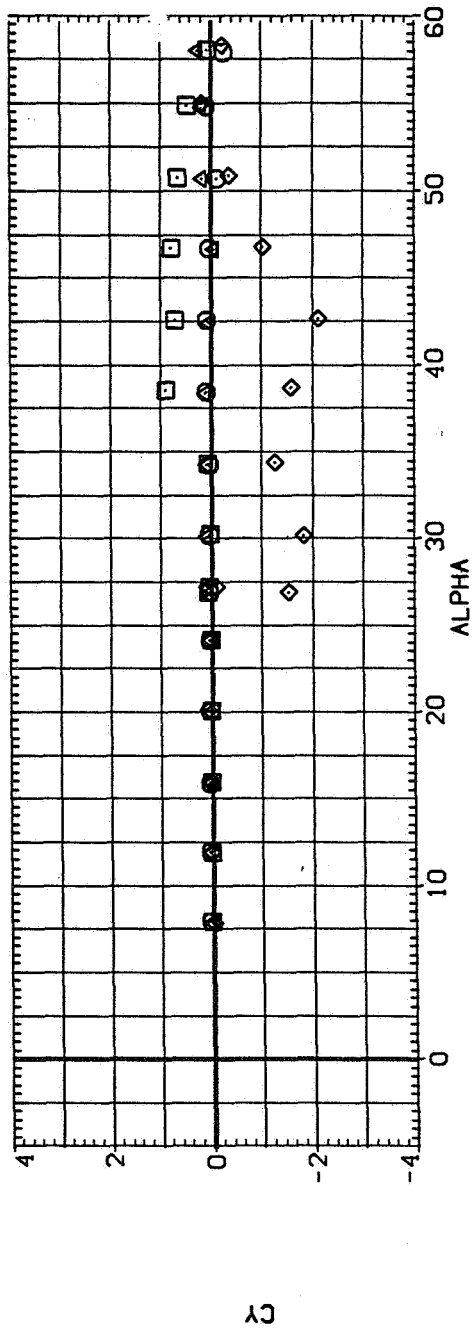
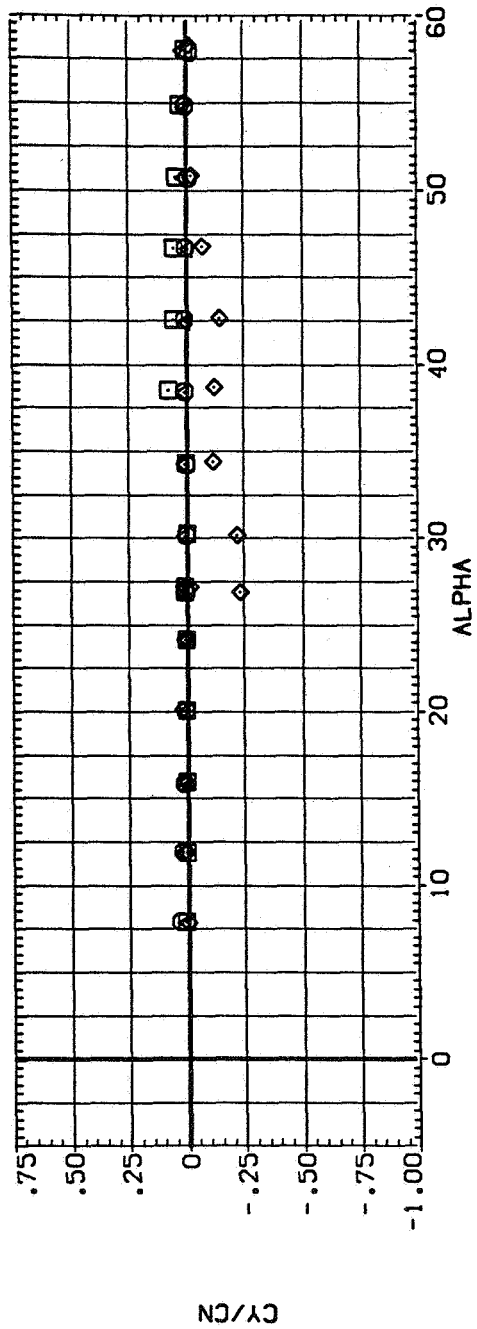
SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N3 C1 S  
 N7 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 4.— Effect of nose fineness ratio;  $M = 0.9$ ,  $Re = 6.5 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N3 C1 S  
 N7 C1 S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 4.— Continued.

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1 C1 S  
 $\square$  N2 C1 S  
 $\square$  N3 C1 S  
 $\square$  N7 C1 S

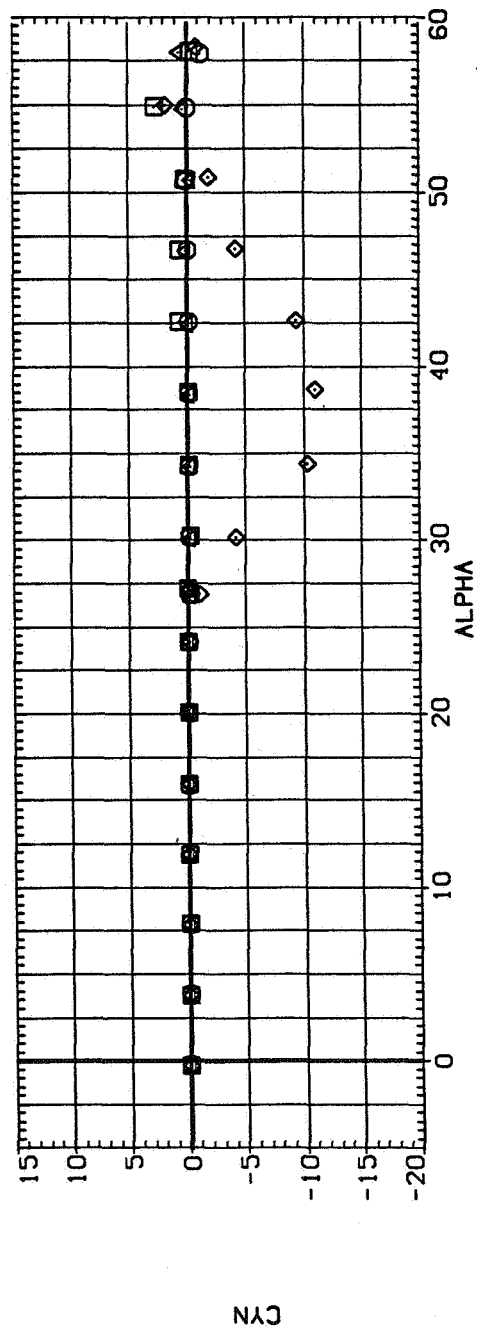
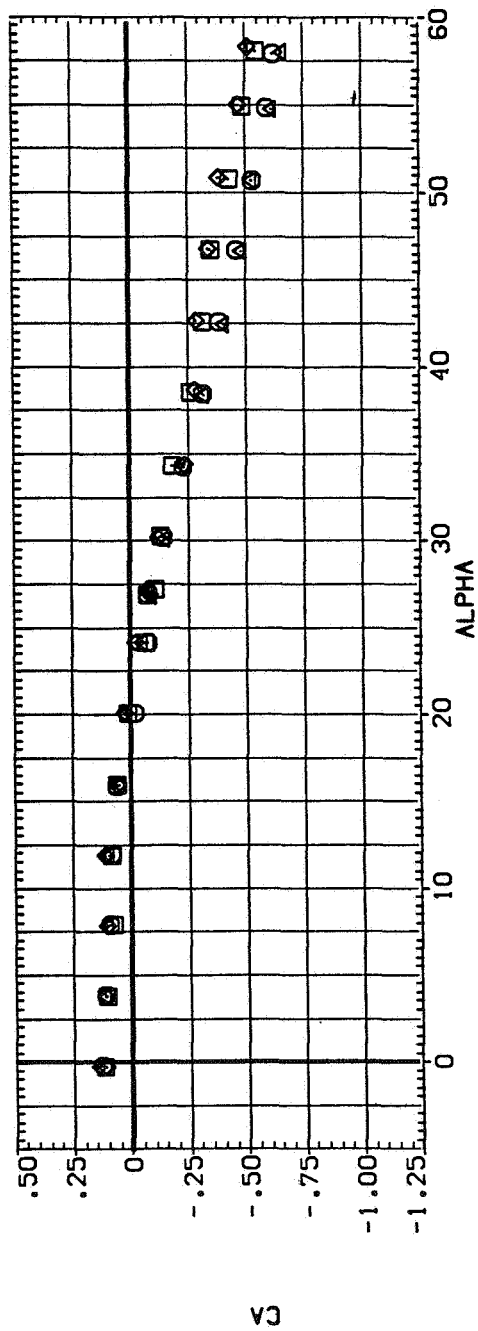
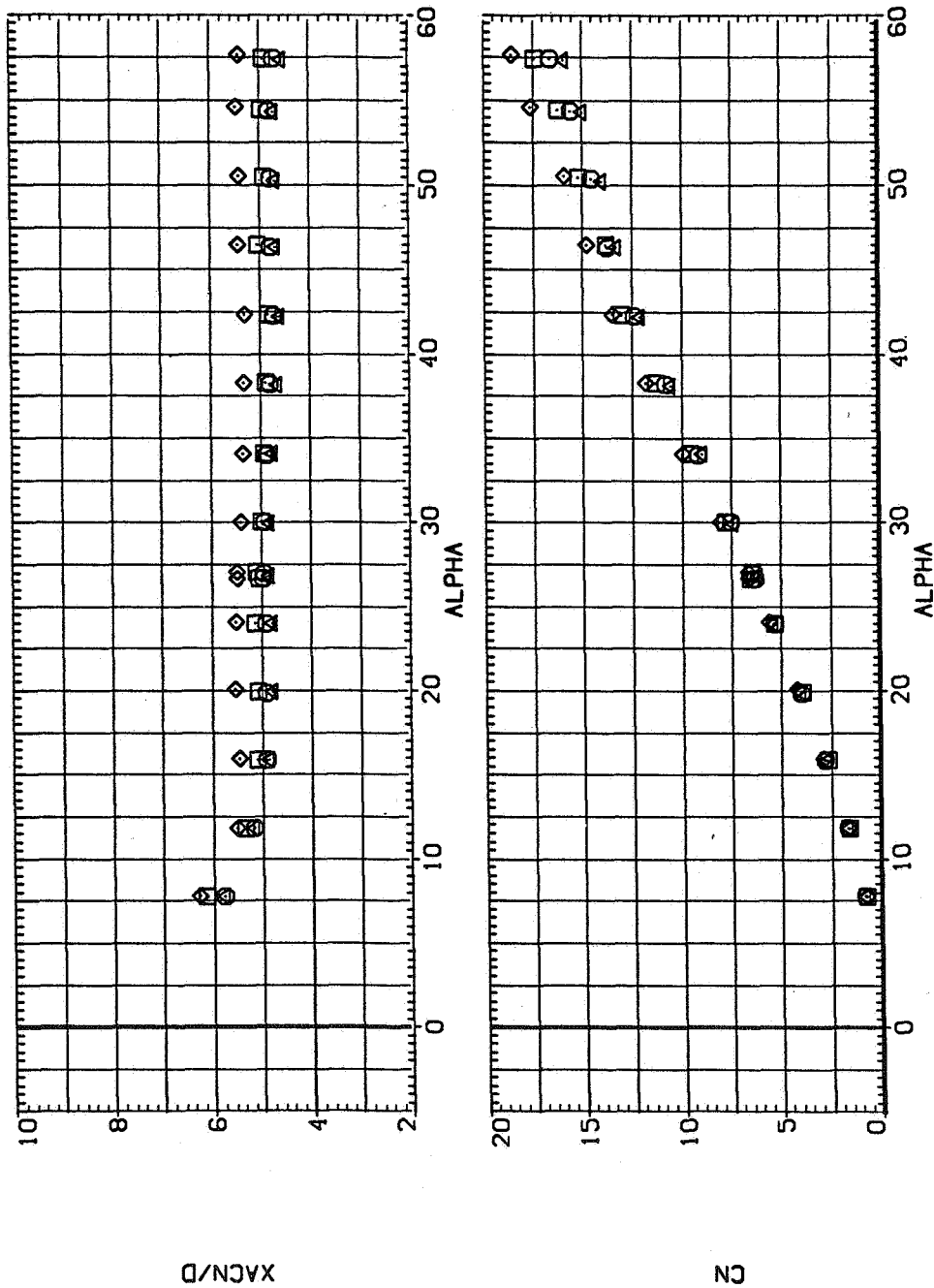
(c)  $C_A$  and  $C_N$  versus  $\alpha$ .

Figure 4.- Concluded.



SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1  
 $\square$  C1  
 $\square$  S1  
 $\square$  S2  
 $\square$  S3  
 $\square$  S4  
 $\square$  S5  
 $\square$  S6  
 $\square$  S7  
 $\square$  S8  
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 $\square$  S96  
 $\square$  S97  
 $\square$  S98  
 $\square$  S99  
 $\square$  S100



(a)  $x_{ac_N}/d$  and  $C_N$  versus  $\alpha$ .

Figure 5.— Effect of nose fineness ratio;  $M = 1.2$ ,  $Re = 3.8 \times 10^5$ .

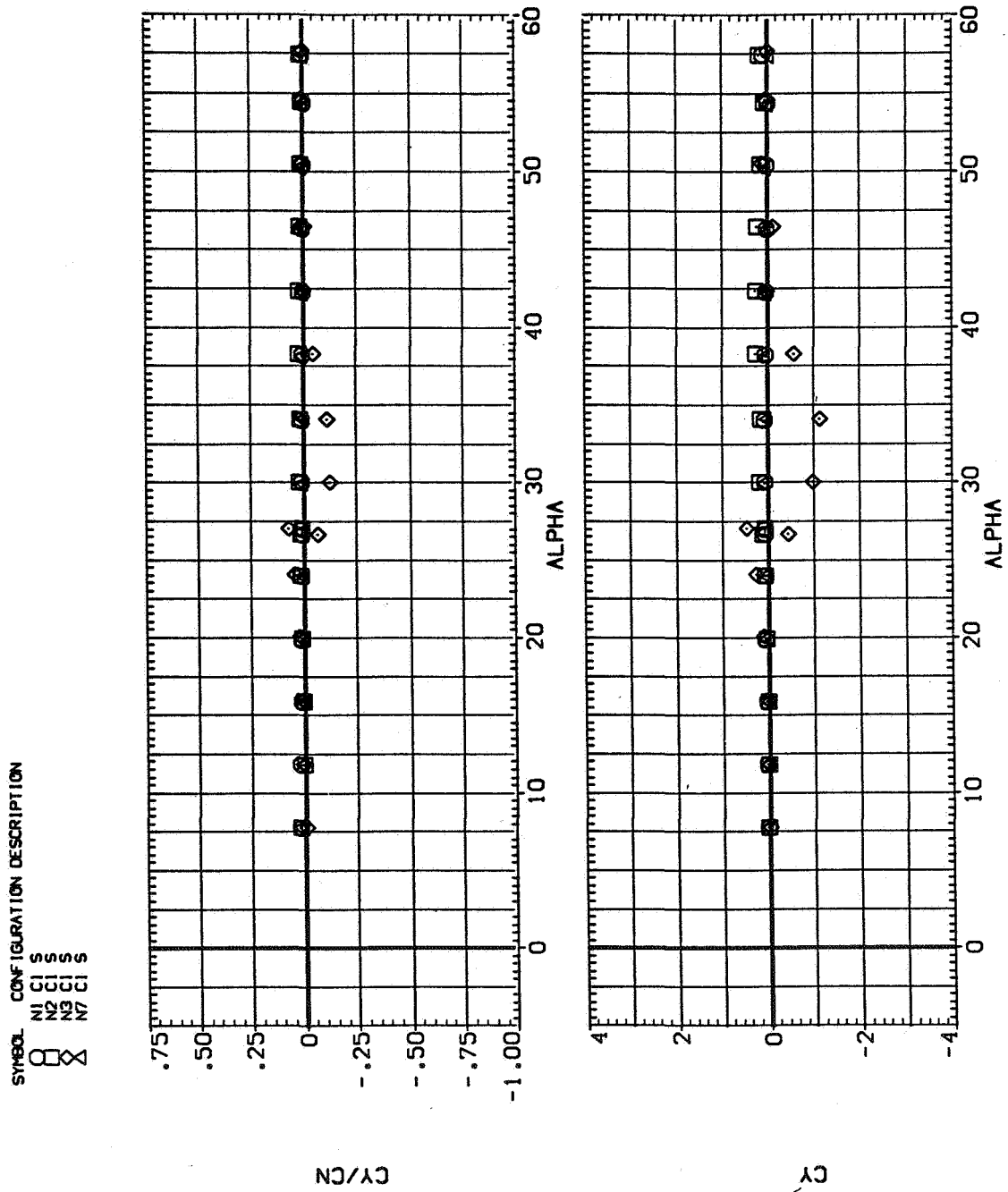
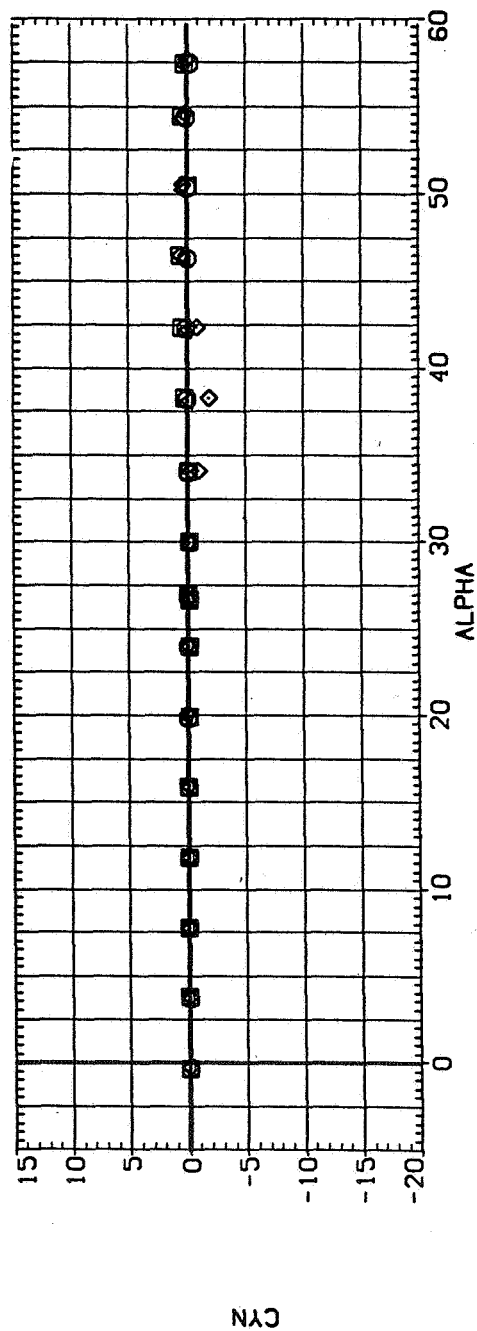
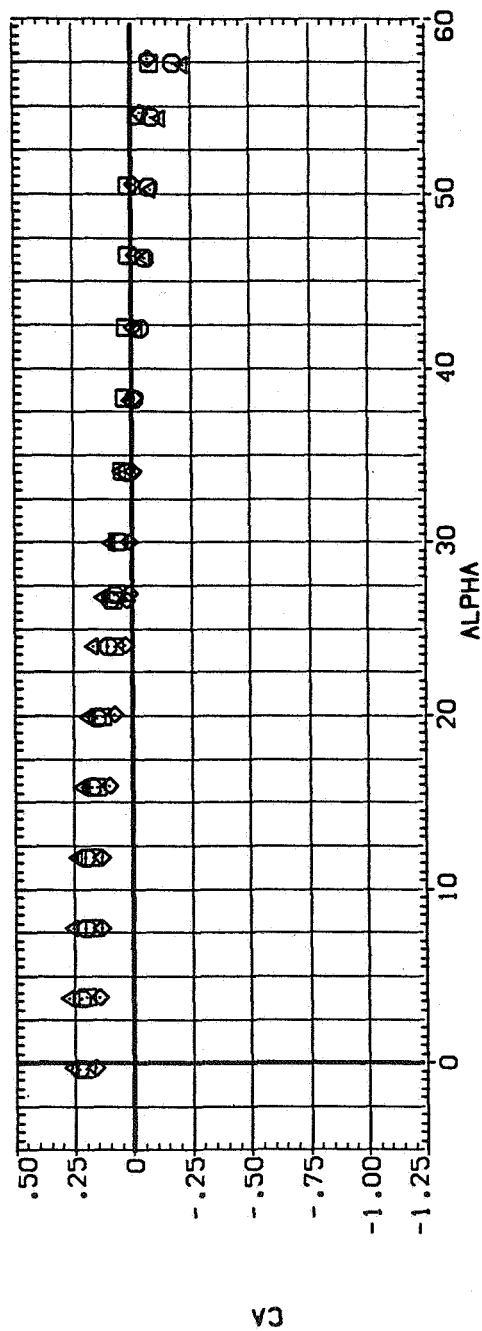


Figure 5.— Continued.

SYMBOL CONFIGURATION DESCRIPTION  
 NI Cl S  
 N2 Cl S  
 N3 Cl S  
 N7 Cl S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 5.— Concluded.

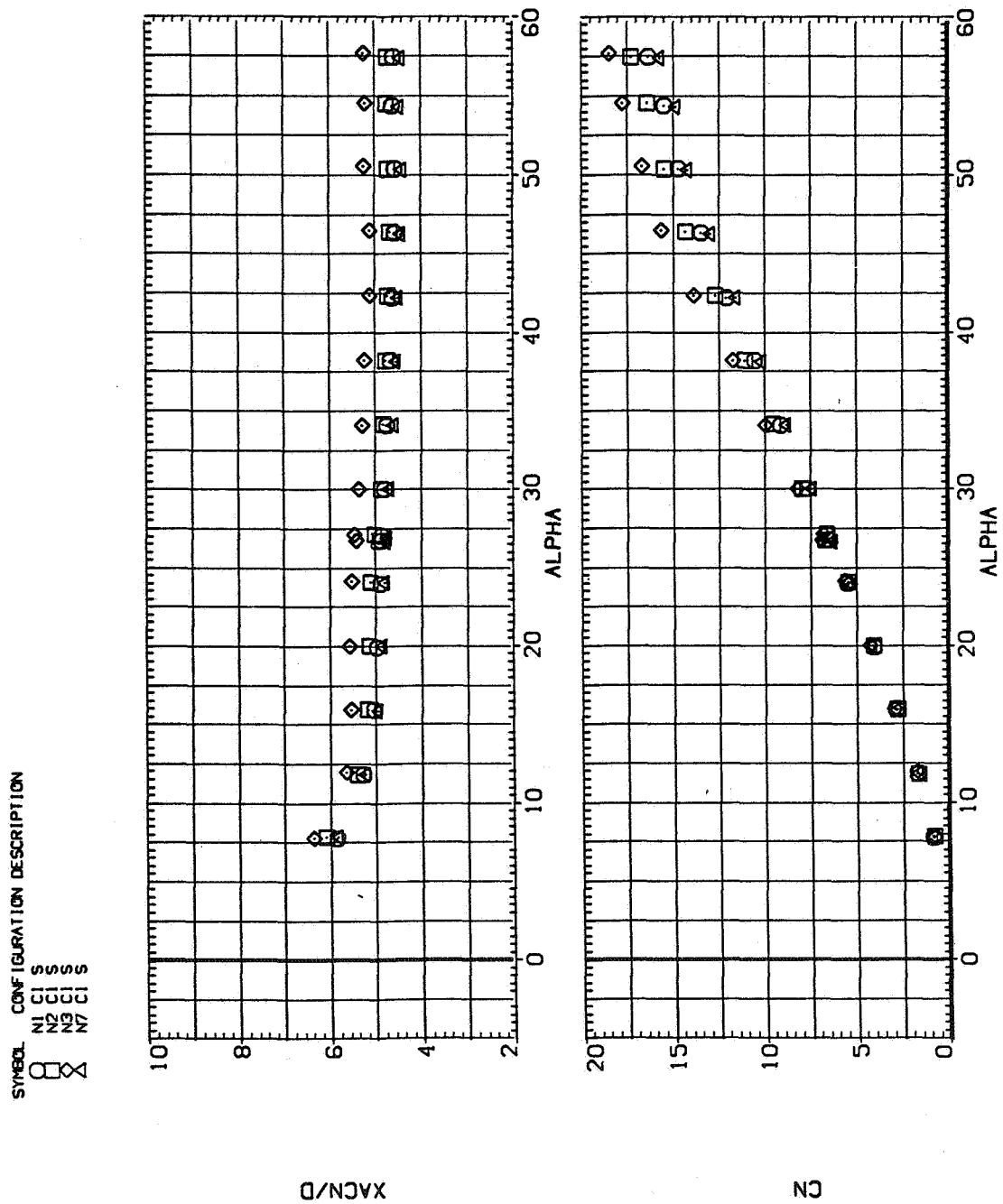
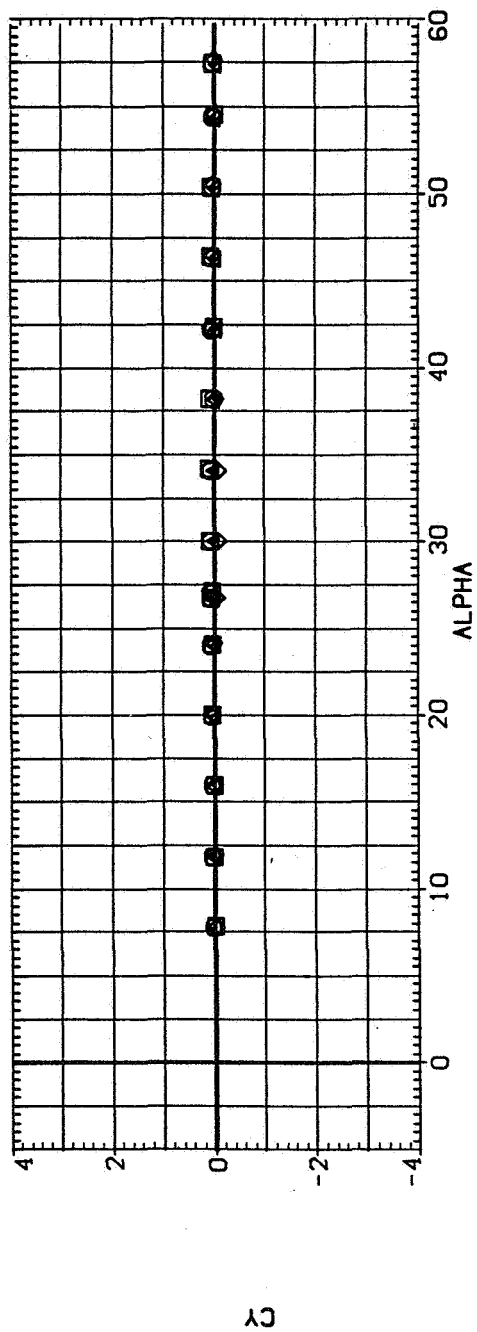
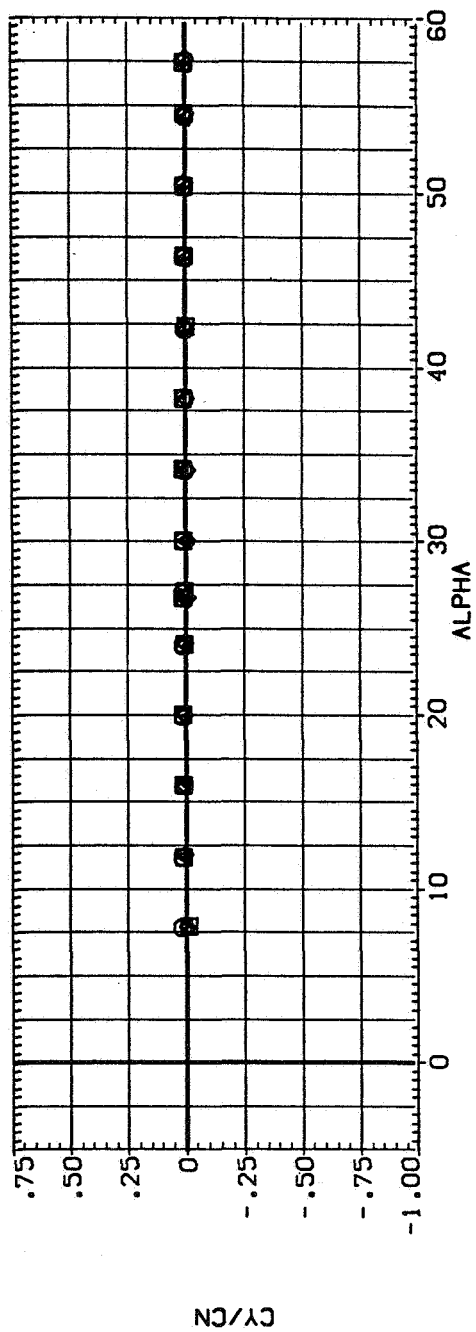


Figure 6.— Effect of nose fineness ratio;  $M = 1.5$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 N2 CI S  
 N3 CI S  
 N7 CI S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 6.— Continued.

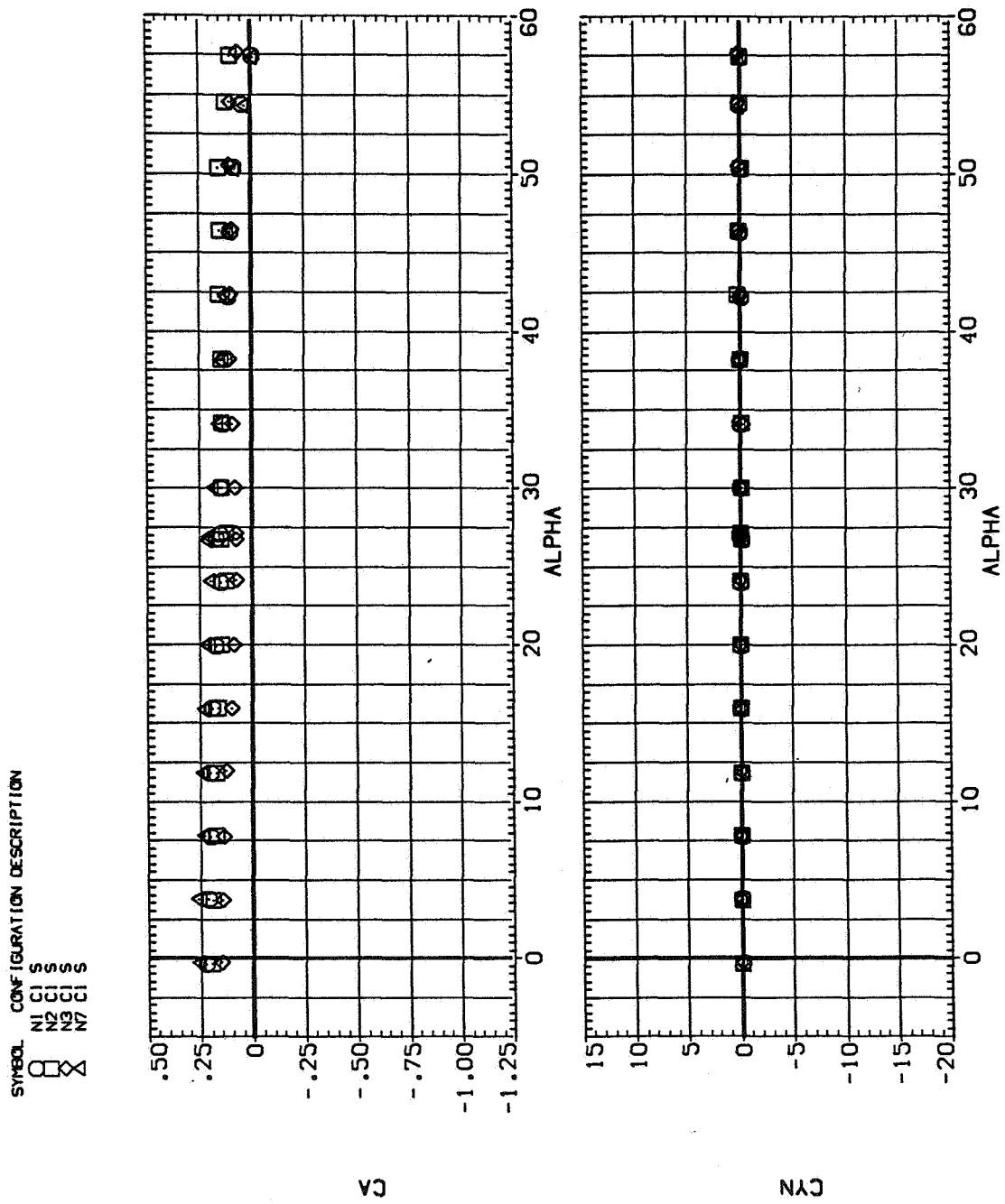
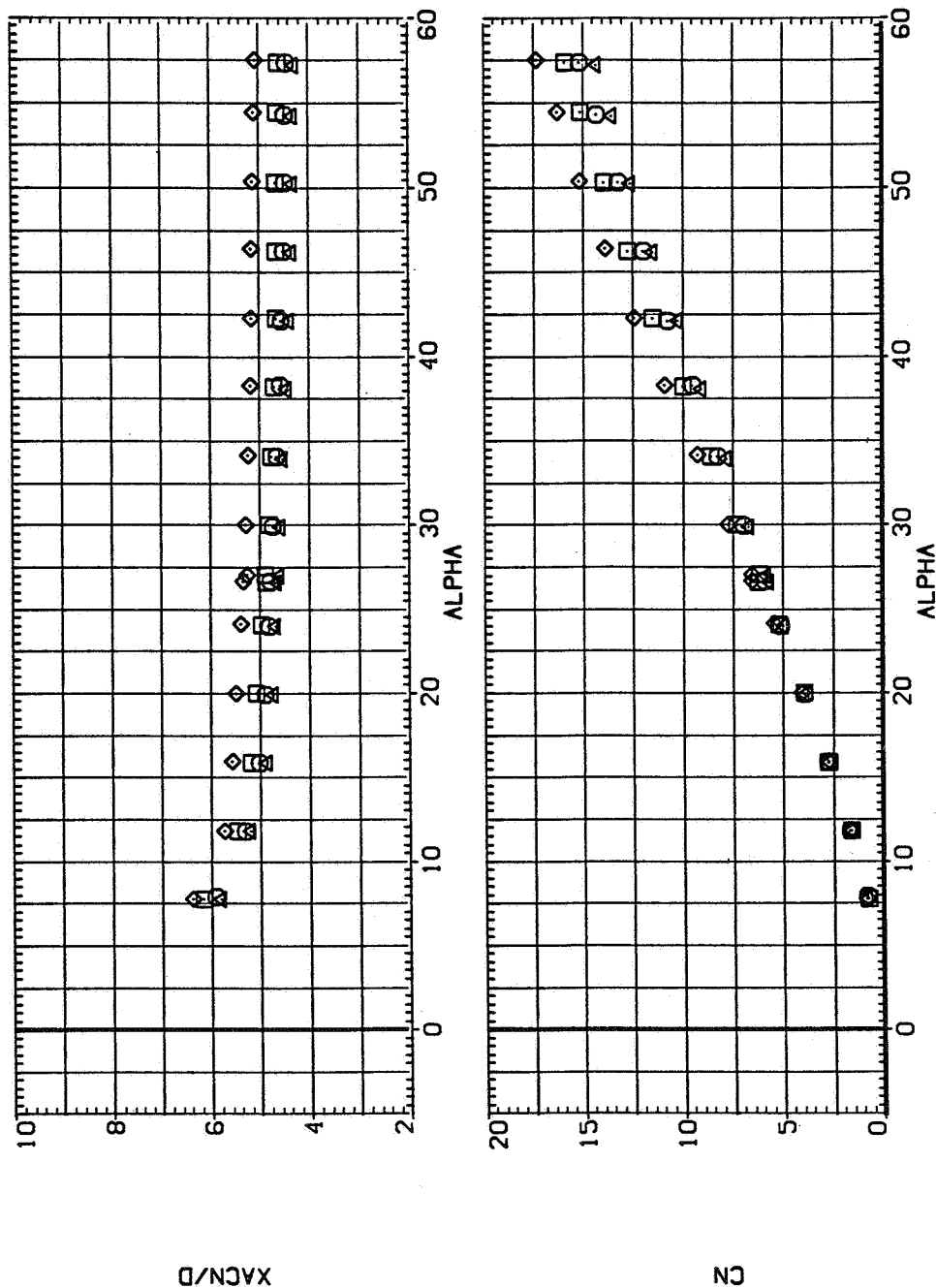
(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 6.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N3 C1 S  
 N7 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 7.— Effect of nose fineness ratio;  $M = 2.0$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1 C1 S  
 $\square$  N2 C1 S  
 $\square$  N3 C1 S  
 $\square$  N7 C1 S

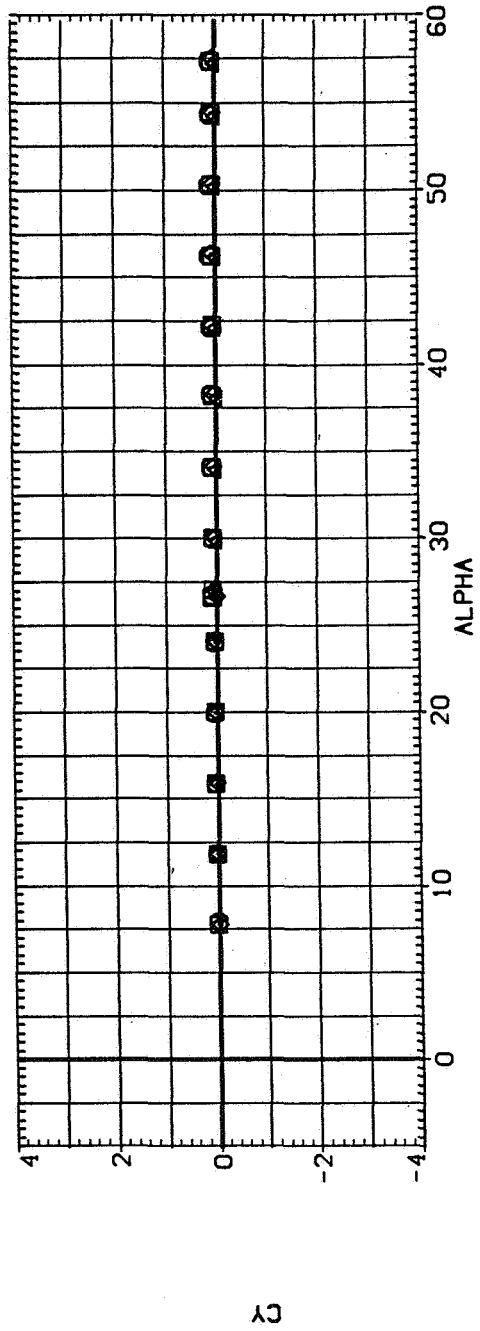
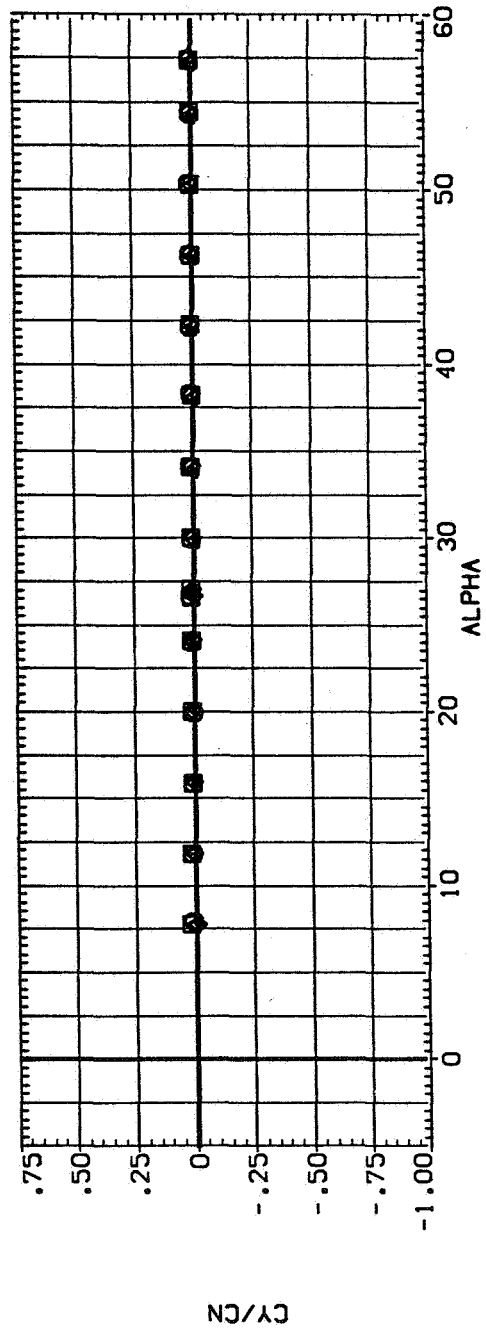
(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

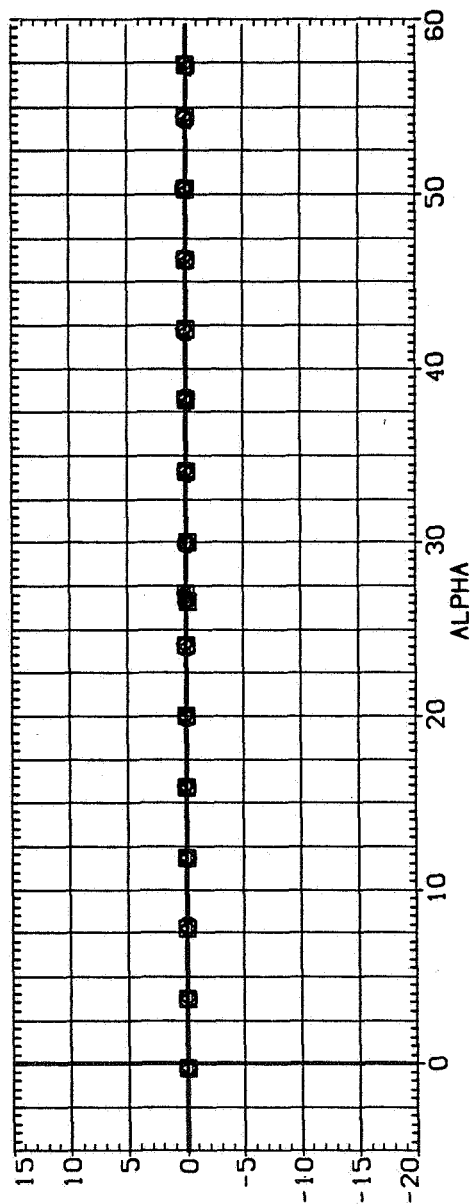
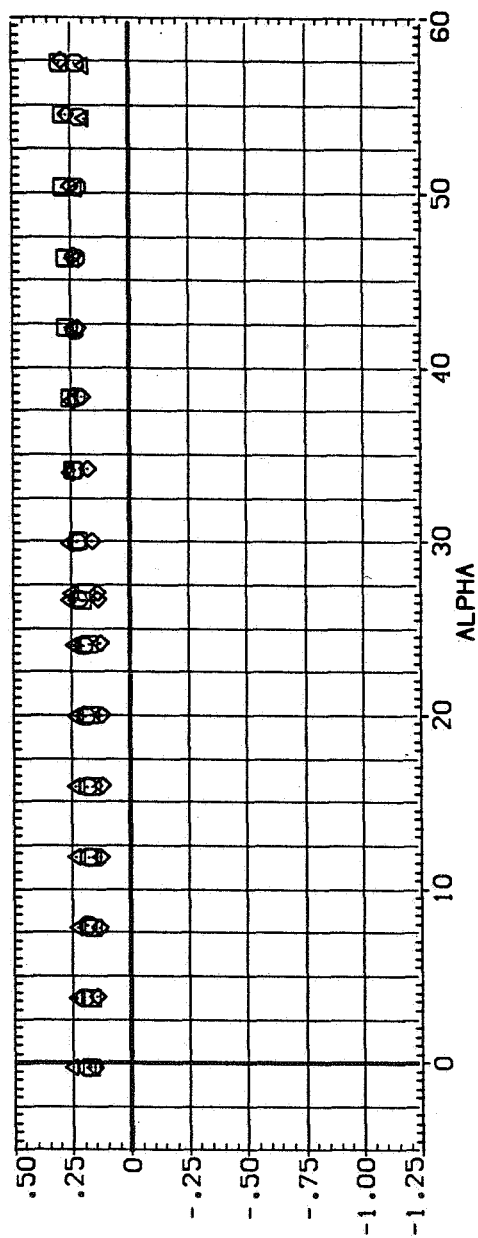
Figure 7.— Continued.



SYMBOL CONFIGURATION DESCRIPTION

N1 C1 S  
N2 C1 S  
N3 C1 S  
N7 C1 S

□  
⊗  
⊙

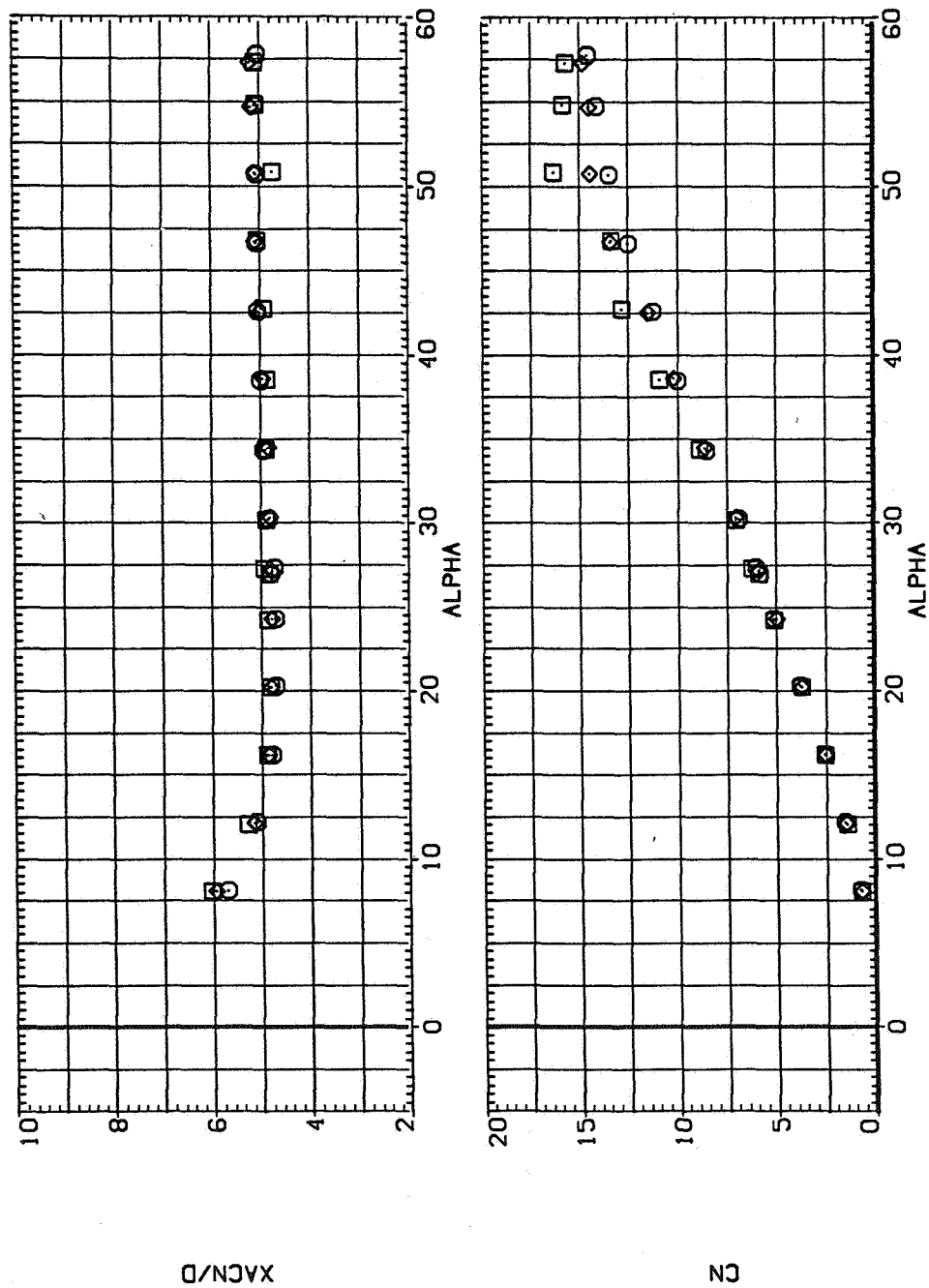


(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 7.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION

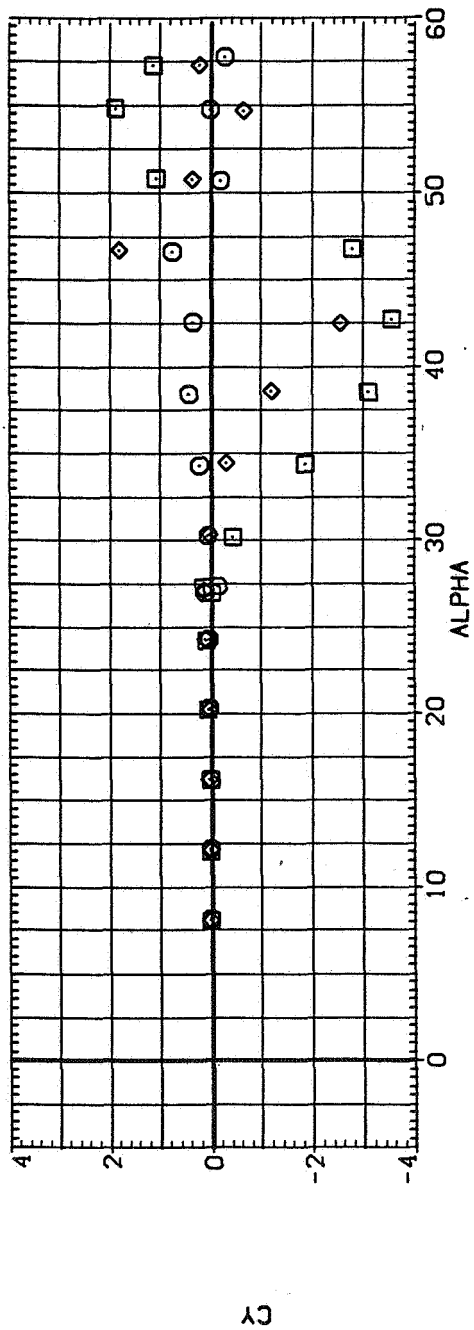
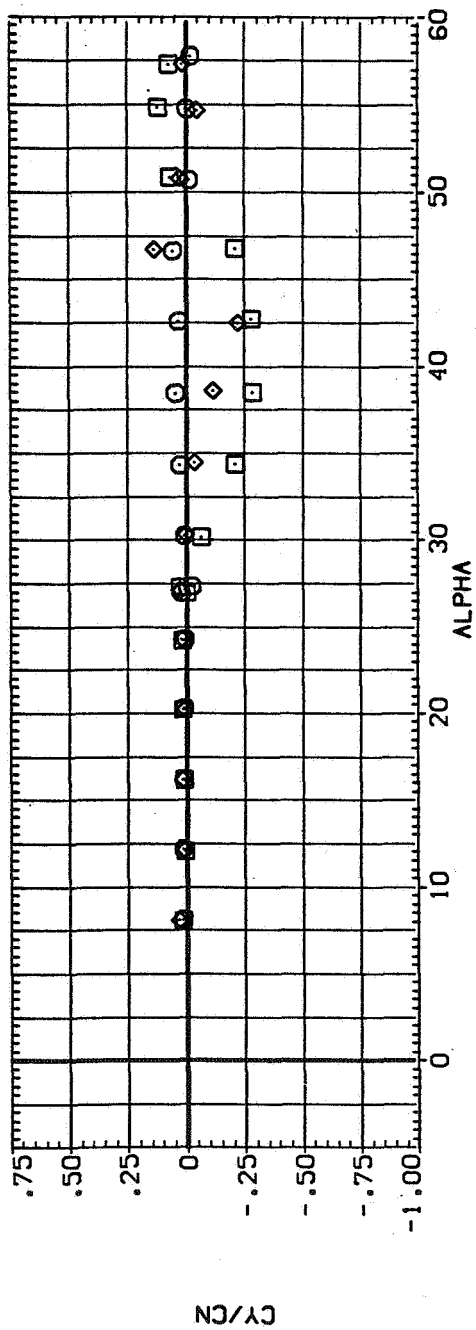
$\square$  N1 C1 S  
 $\diamond$  N2 C1 S  
 $\square$  N4 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 8.— Effect of nose tip rounding;  $M = 0.6$ ,  $Re = 6.5 \times 10^5$ .

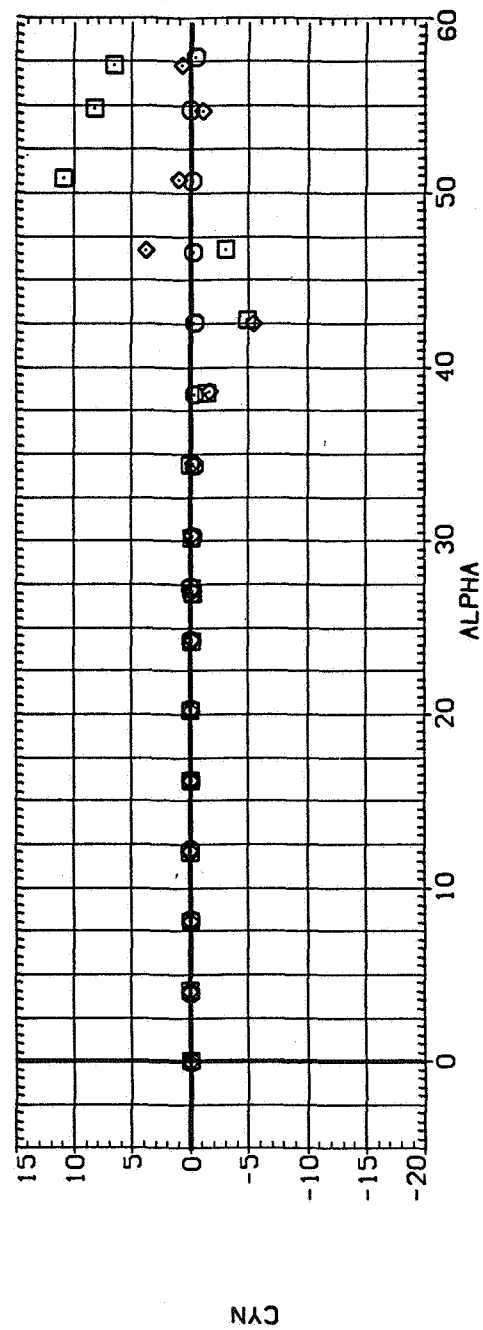
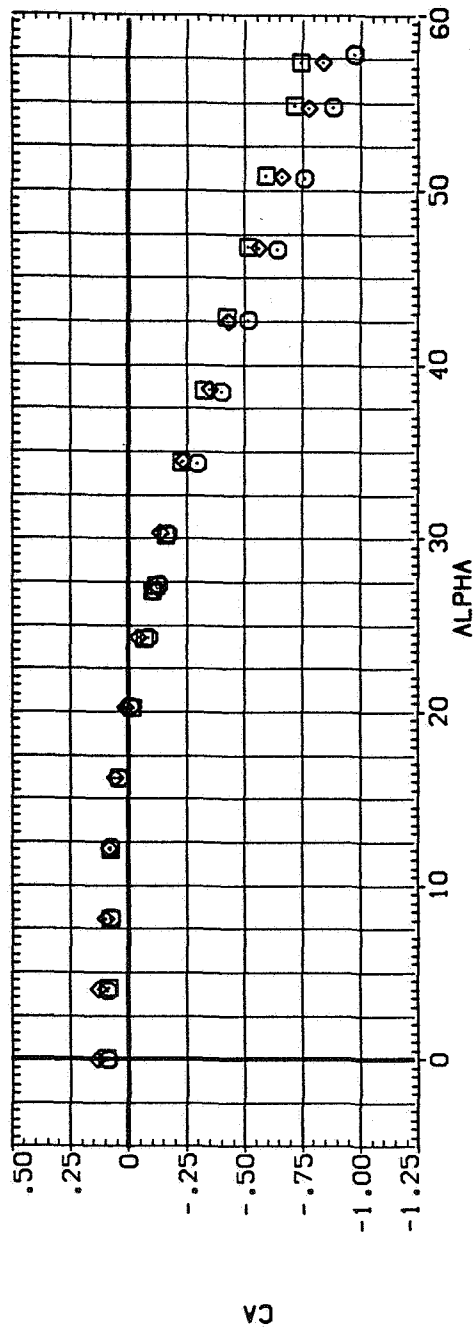
SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N4 C1 S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 8.— Continued.

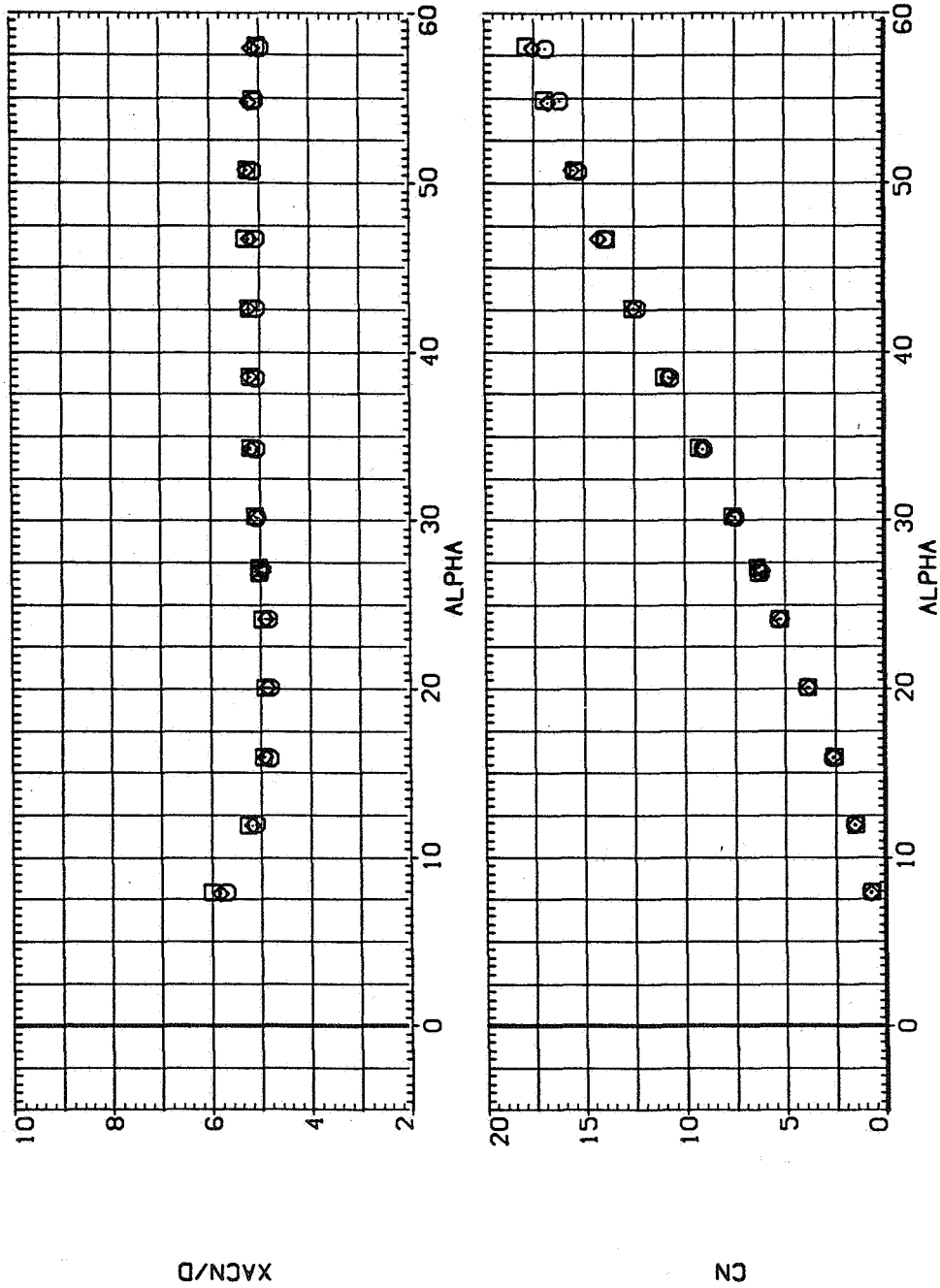
SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N4 C1 S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 8.— Concluded.

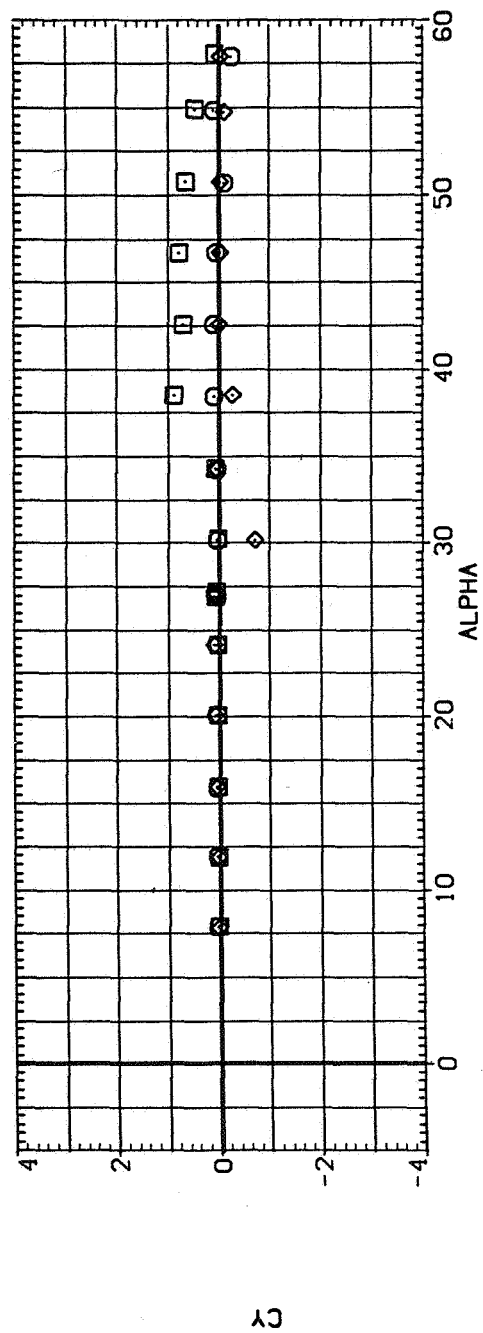
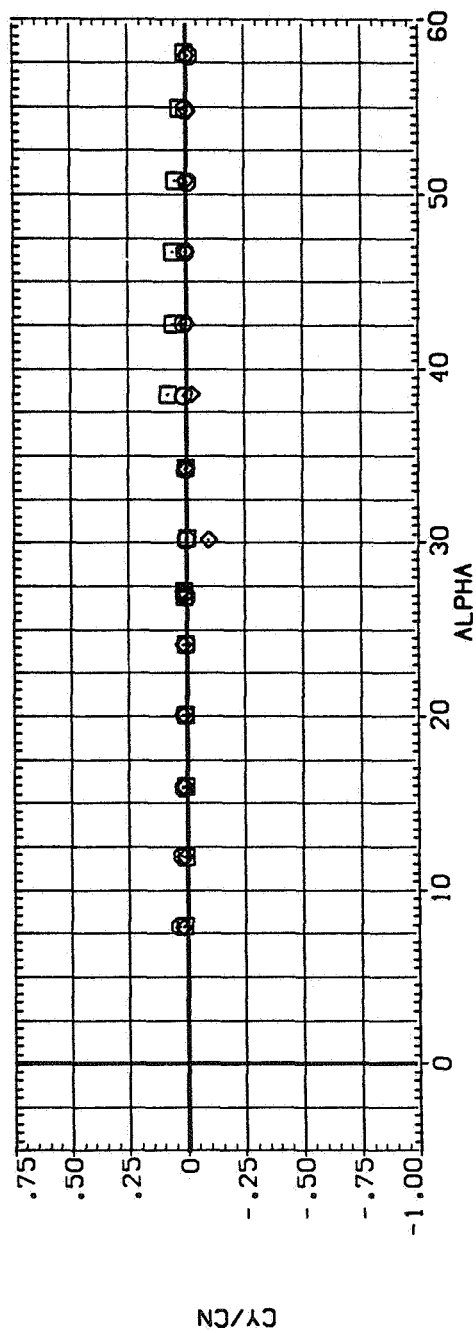
SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N4 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 9.— Effect of nose tip rounding;  $M = 0.9$ ,  $Re = 6.5 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 N1 Cl S  
 N2 Cl S  
 N4 Cl S

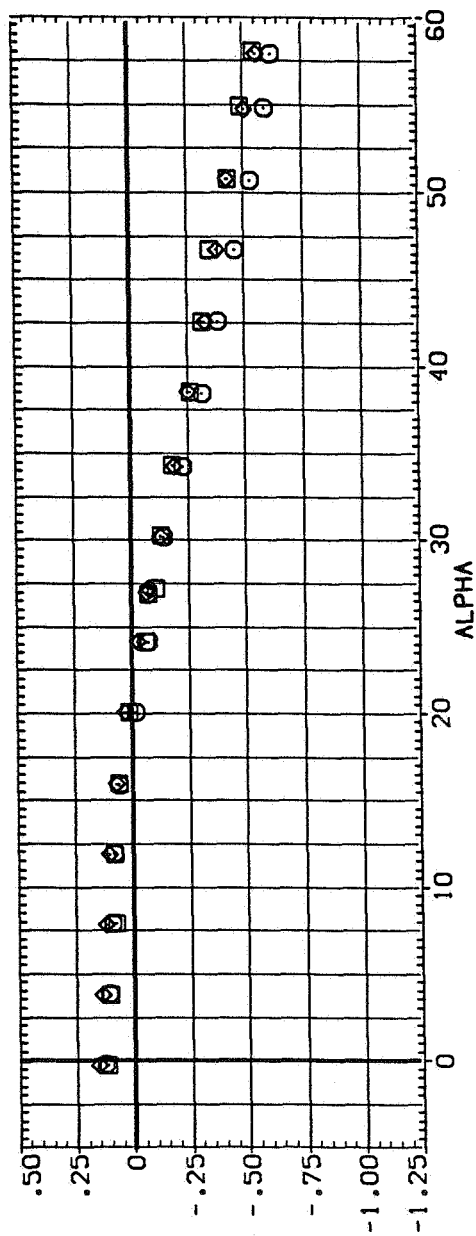


(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

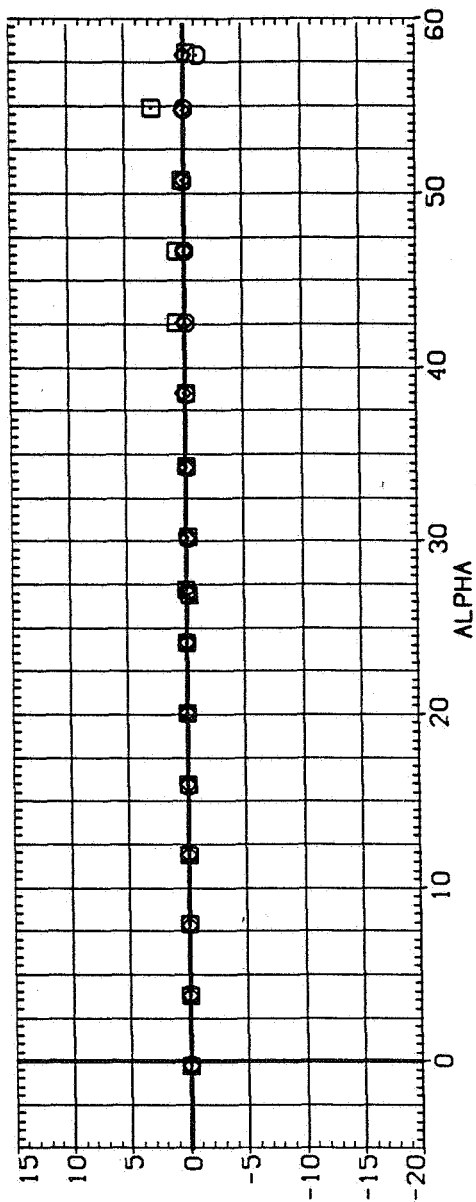
Figure 9. — Continued.

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1 Cl S  
 $\diamond$  N2 Cl S  
 $\square$  N4 Cl S



CA






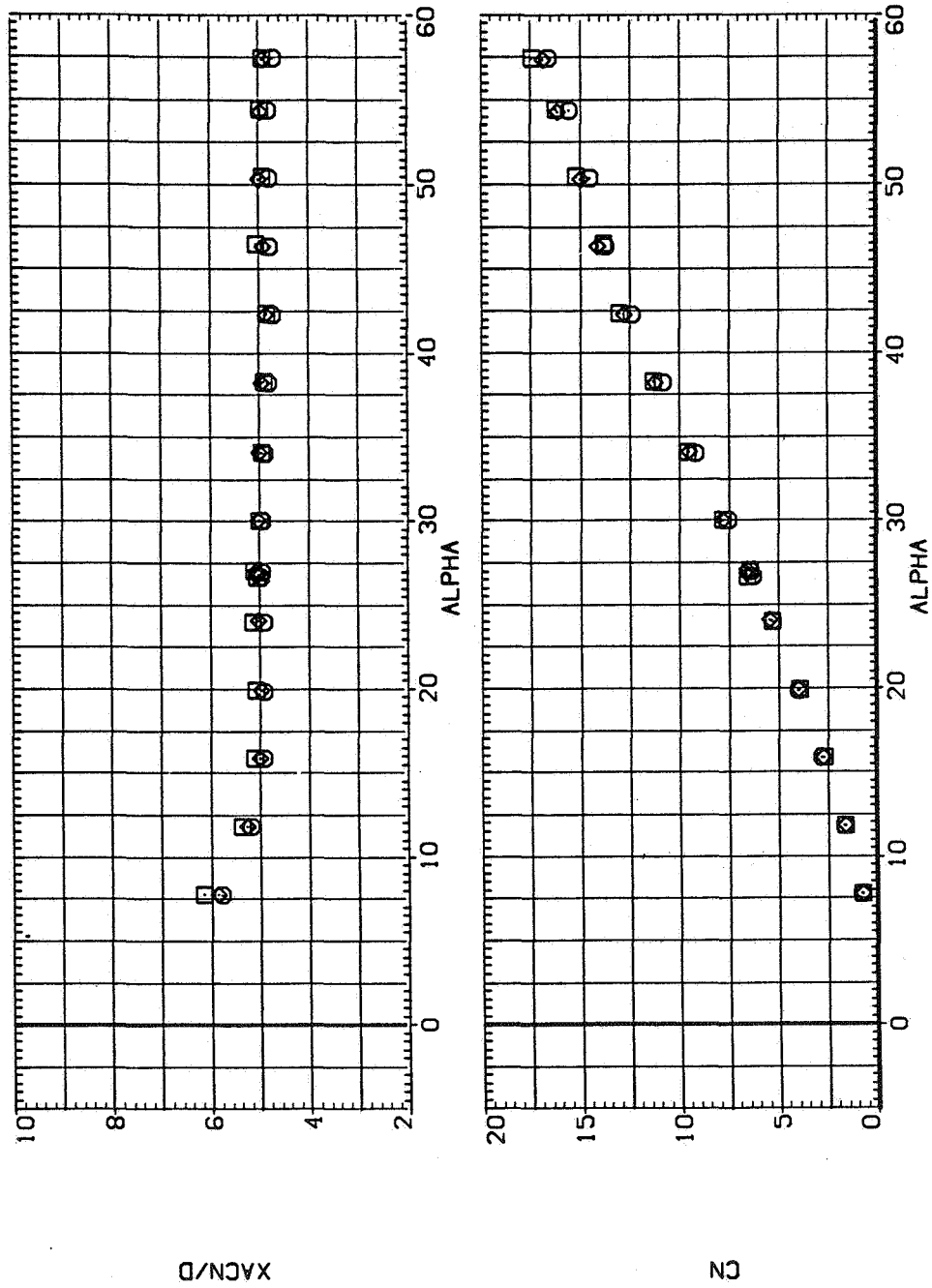
CYN

(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 9.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION

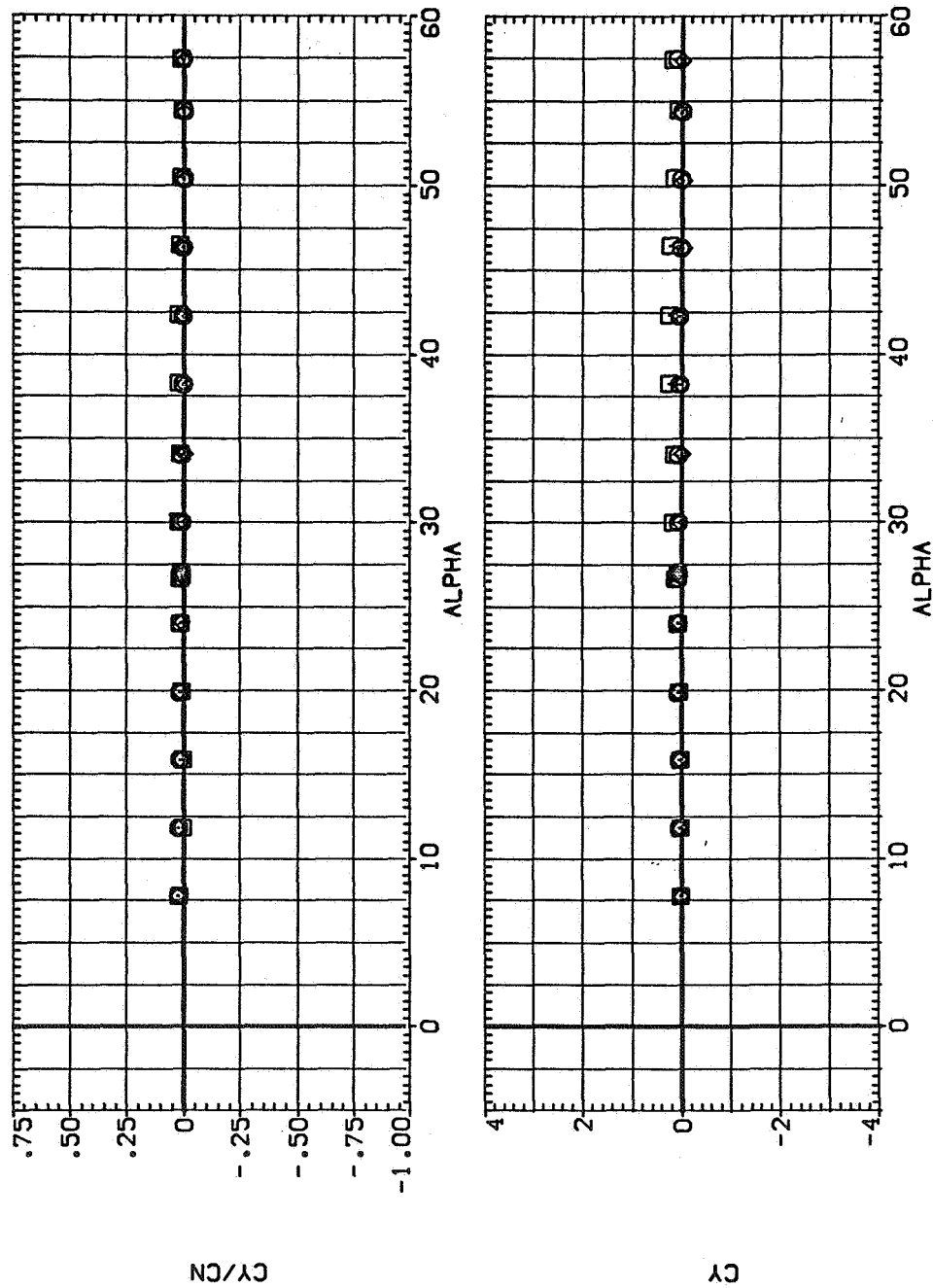
 N1 C1 S  
 N2 C1 S  
 N4 C1 S

(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .Figure 10.— Effect of nose tip rounding;  $M = 1.2$ ,  $Re = 3.8 \times 10^5$ .



SYMBOL CONFIGURATION DESCRIPTION

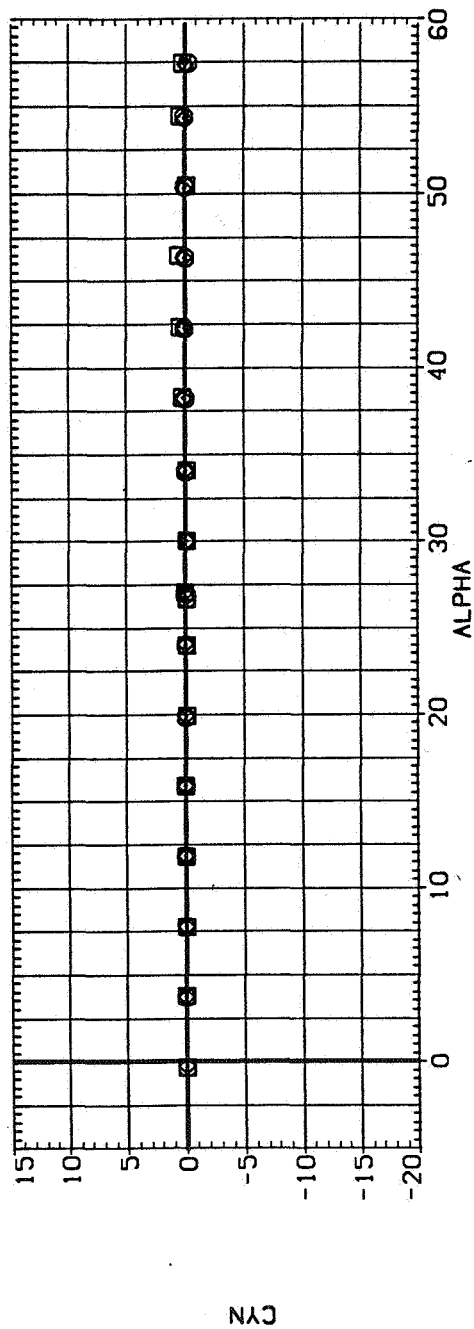
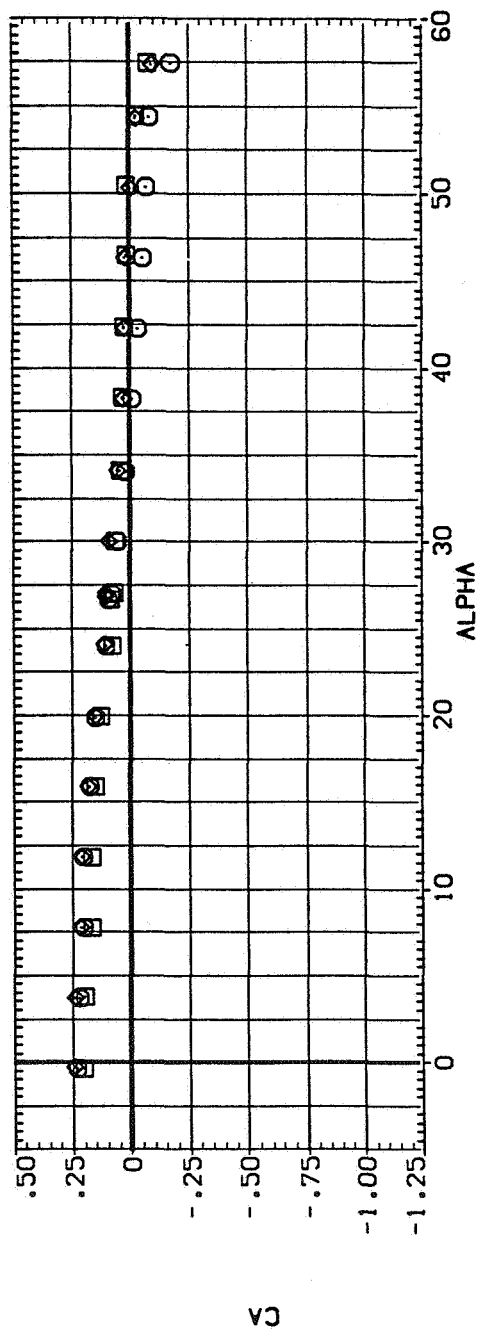
□	N1 C1 S
◻	N2 C1 S
◻	N4 C1 S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 10.— Continued.

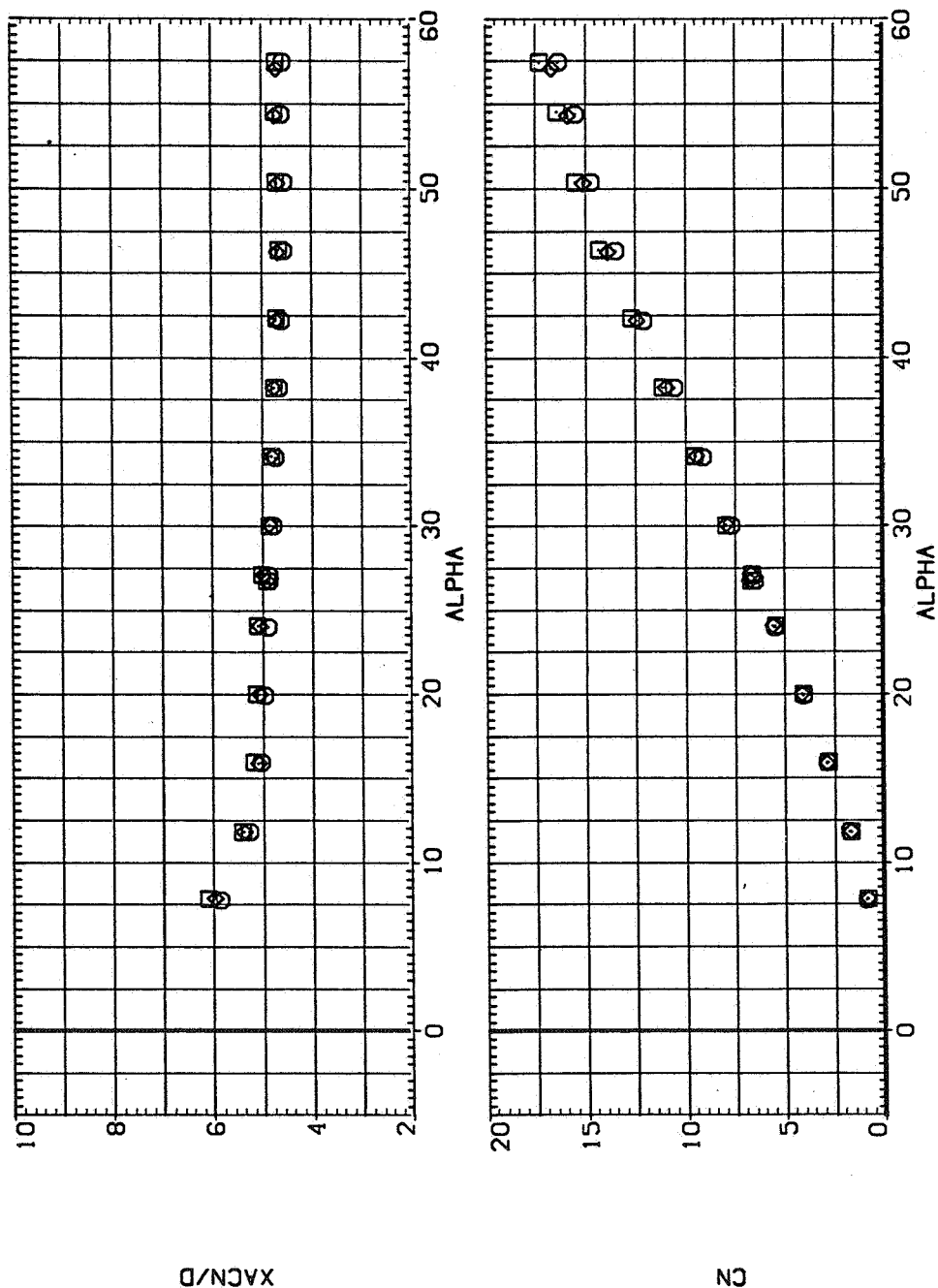
SYMBOL CONFIGURATION DESCRIPTION  
 N1 Cl S  
 N2 Cl S  
 N4 Cl S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 10.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION  
 N1 C1 S  
 N2 C1 S  
 N4 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 11.— Effect of nose tip rounding;  $M = 1.5$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION



N1 Cl S  
N2 Cl S  
N4 Cl S

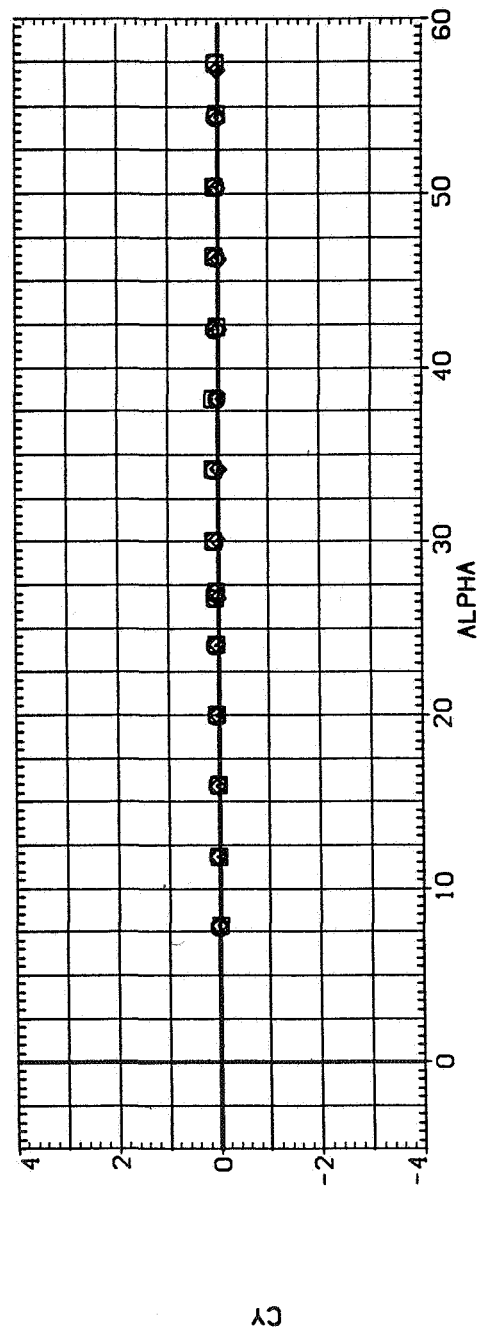
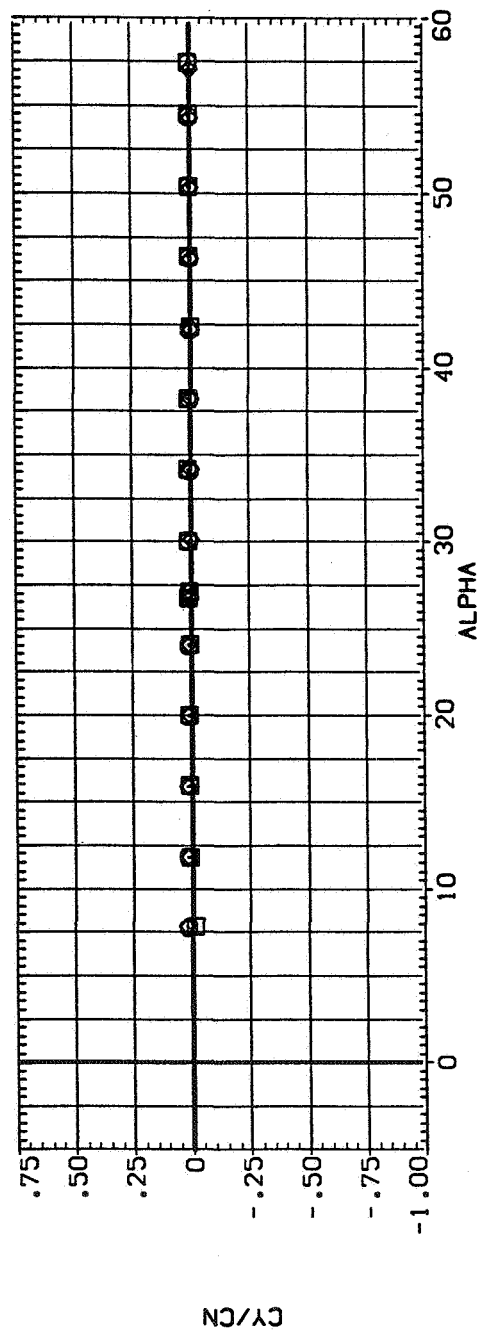
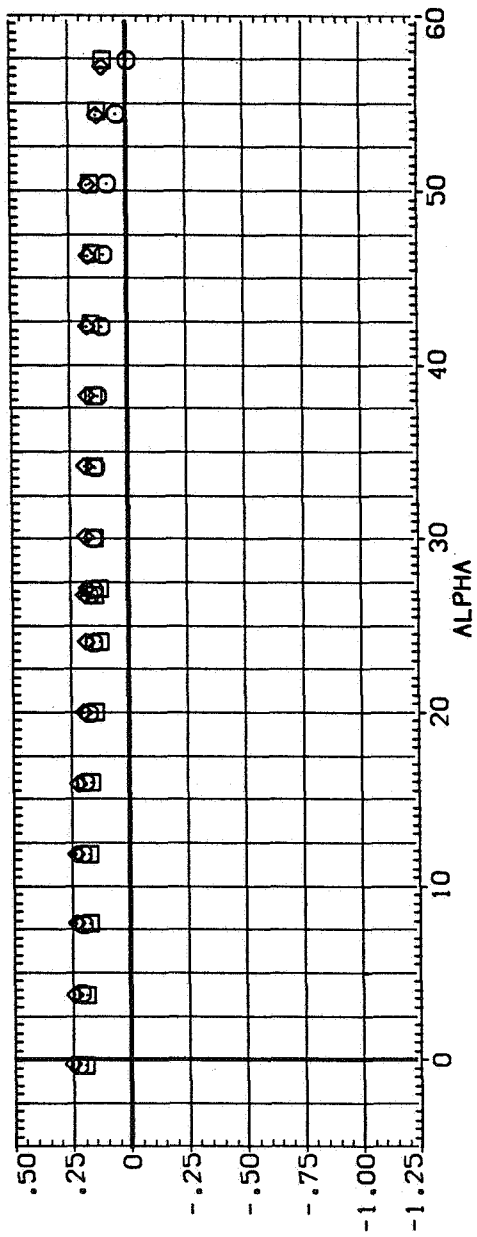
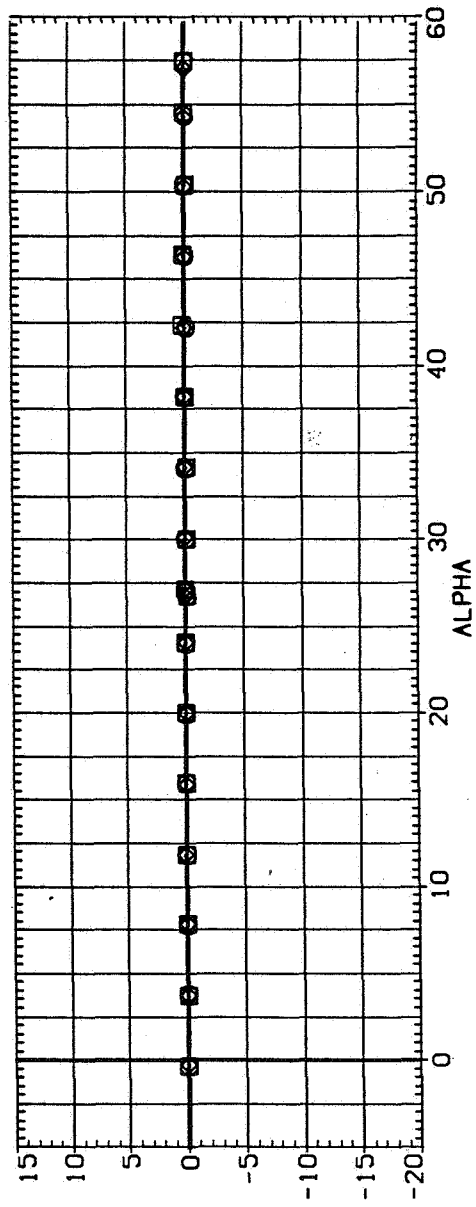
(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 11.— Continued.

SYMBOL CONFIGURATION DESCRIPTION  
 N1 Cl S  
 N2 Cl S  
 N4 Cl S



CA






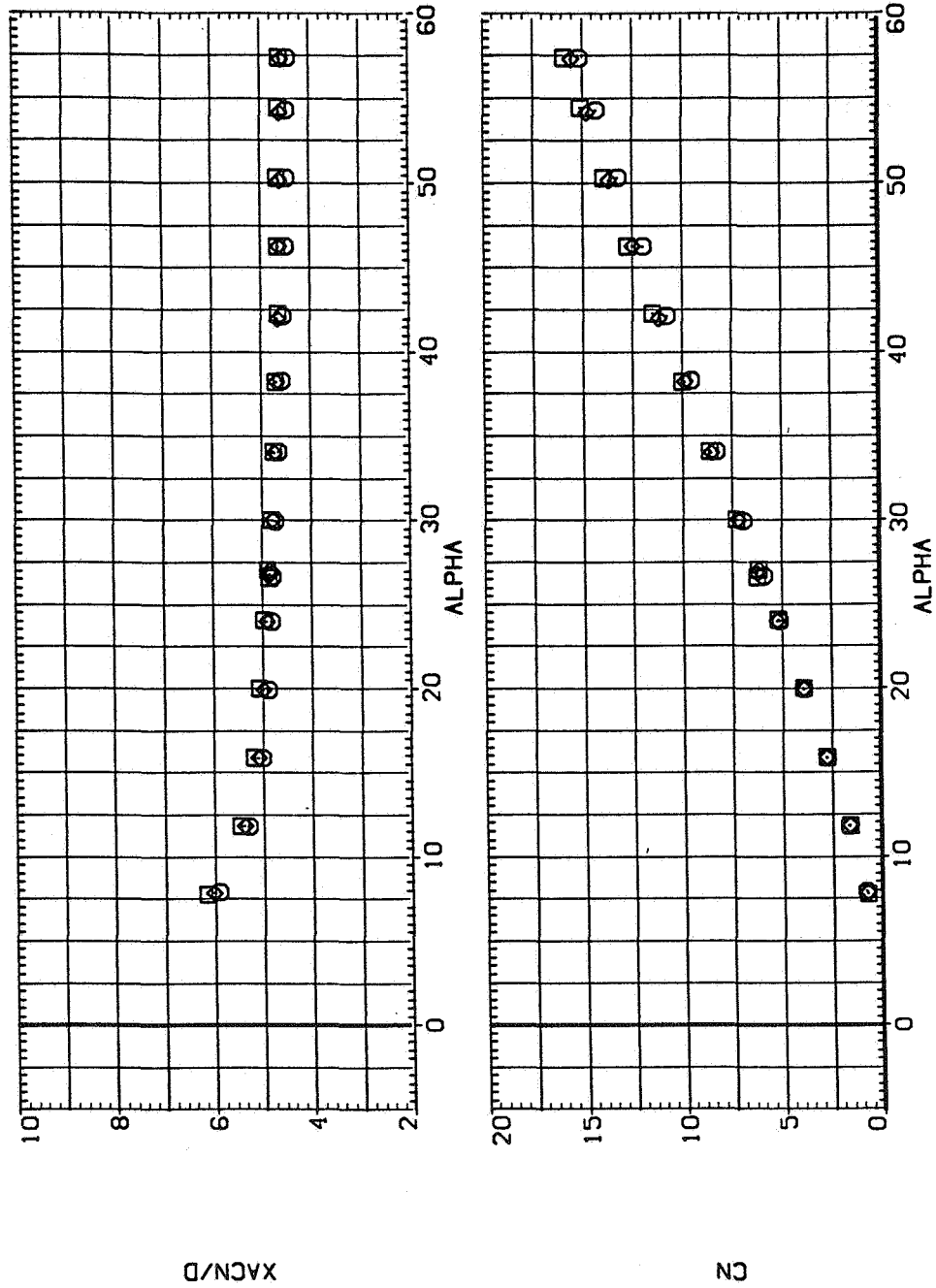
CYN

(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 11.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION

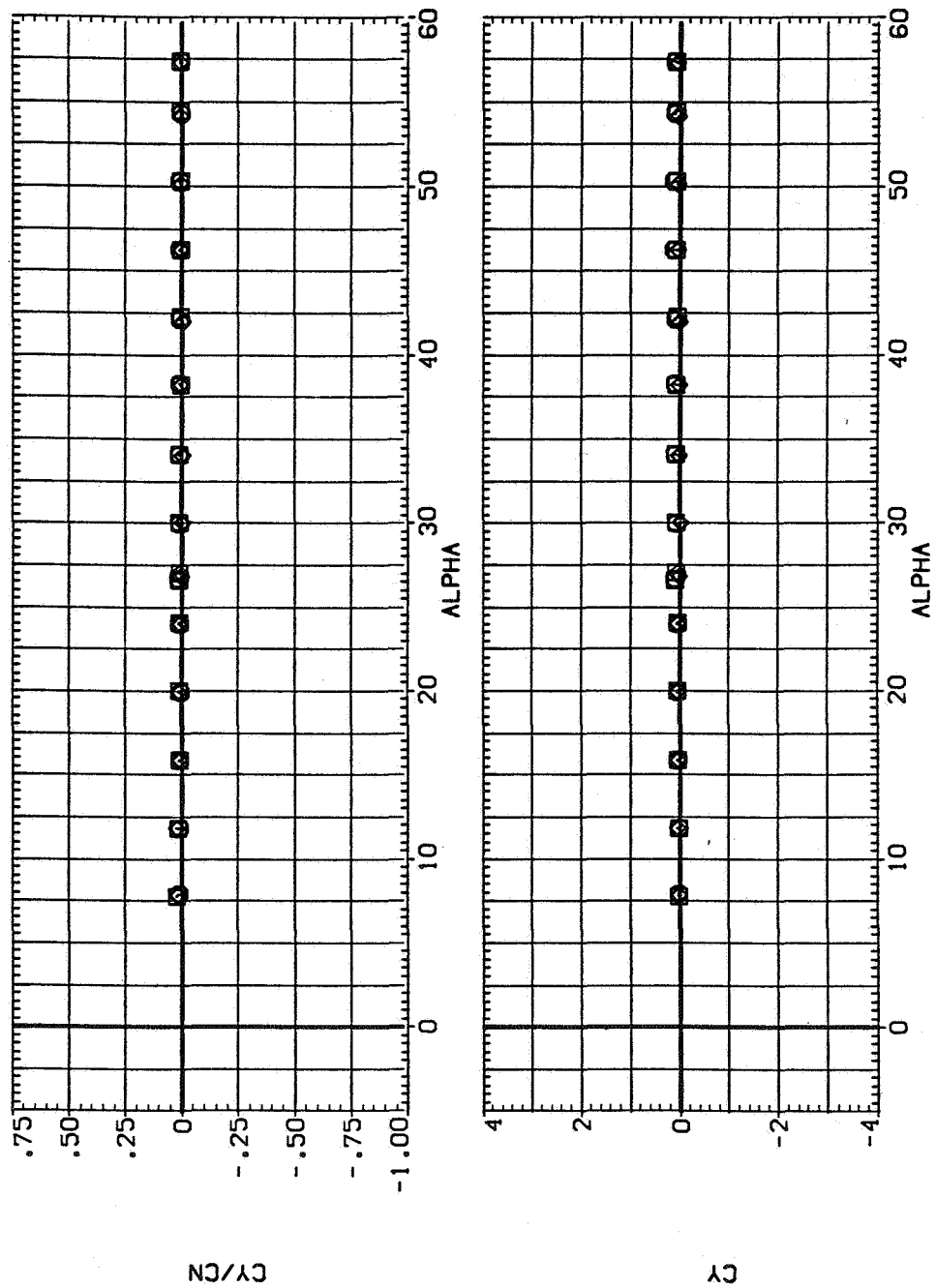
 N1 C1 S  
 N2 C1 S  
 N4 C1 S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 12.— Effect of nose tip rounding:  $M = 2.0$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 N1 Cl S  
 N2 Cl S  
 N4 Cl S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 12.— Continued.

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N1 Cl S  
 $\square$  N2 Cl S  
 $\square$  N4 Cl S

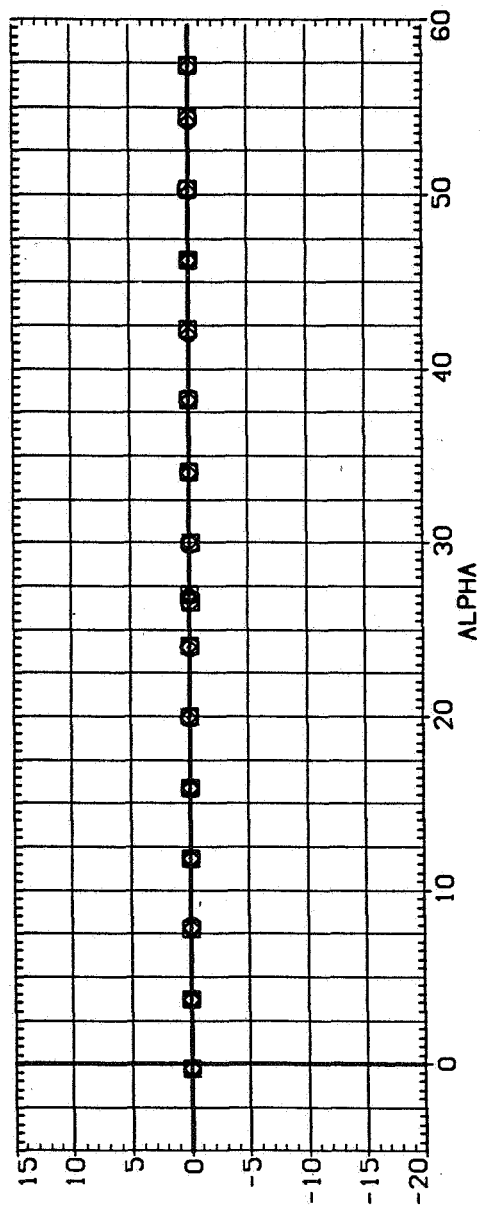
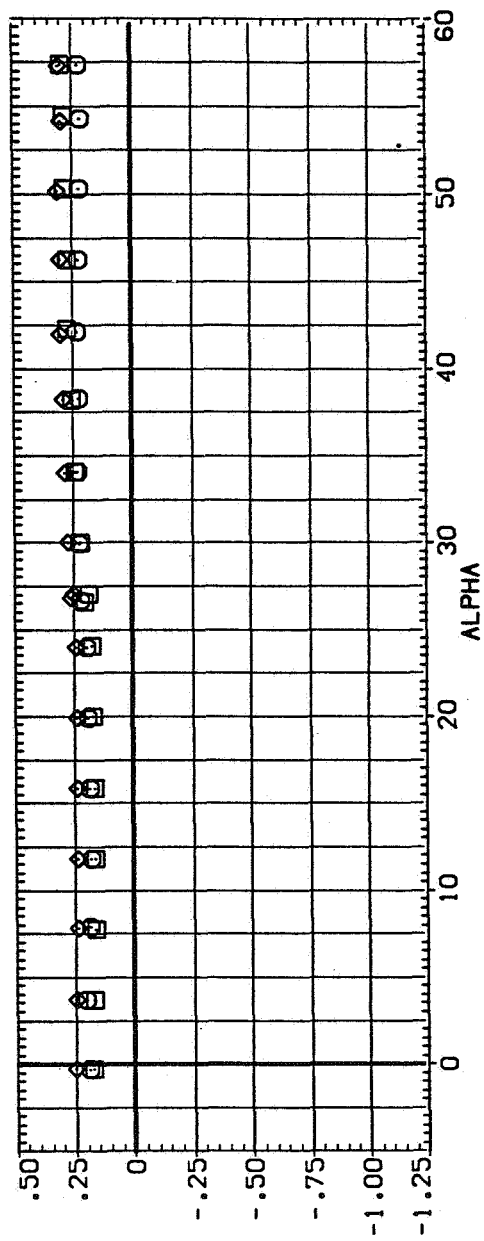
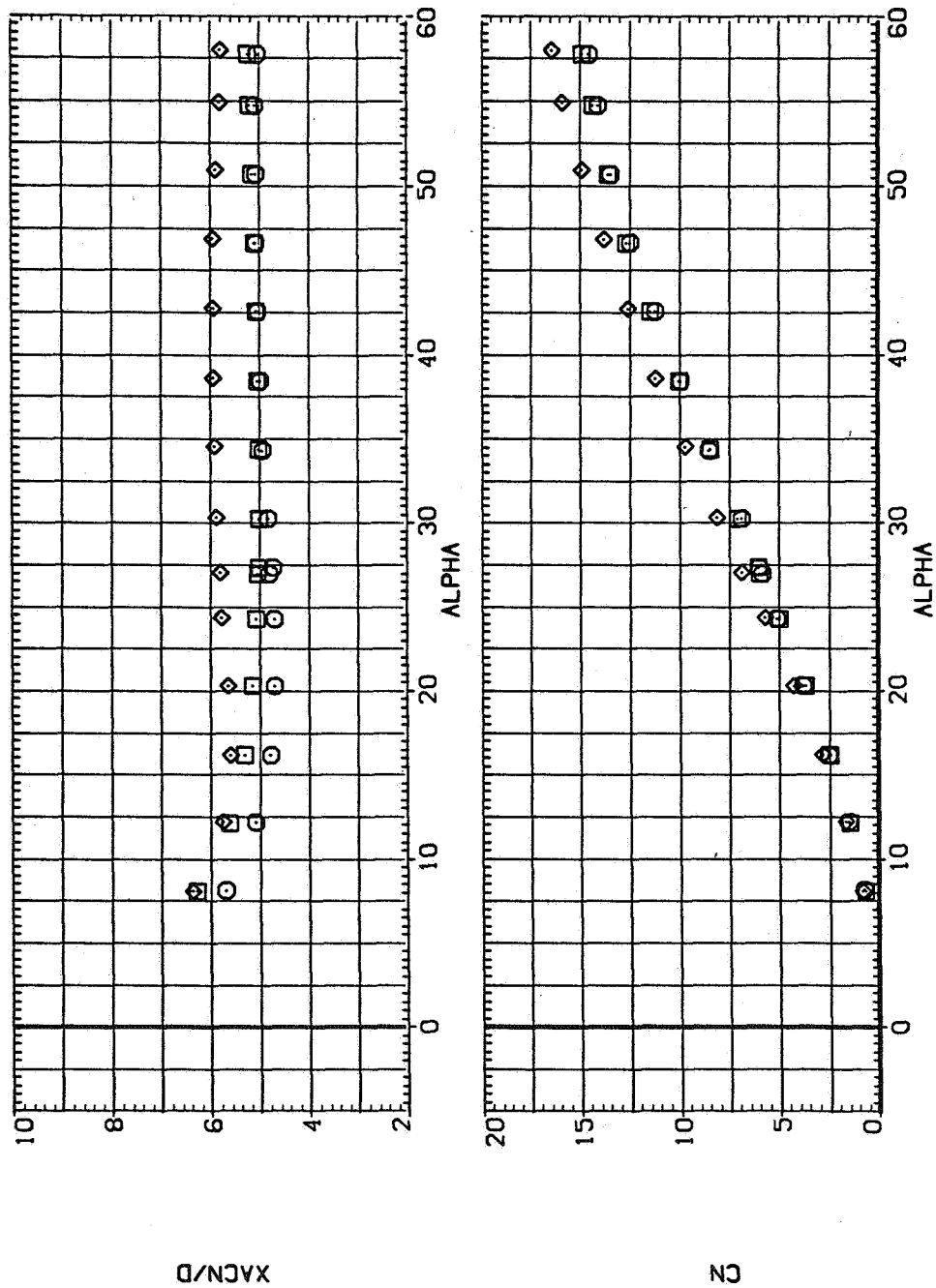
(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 12.— Concluded.



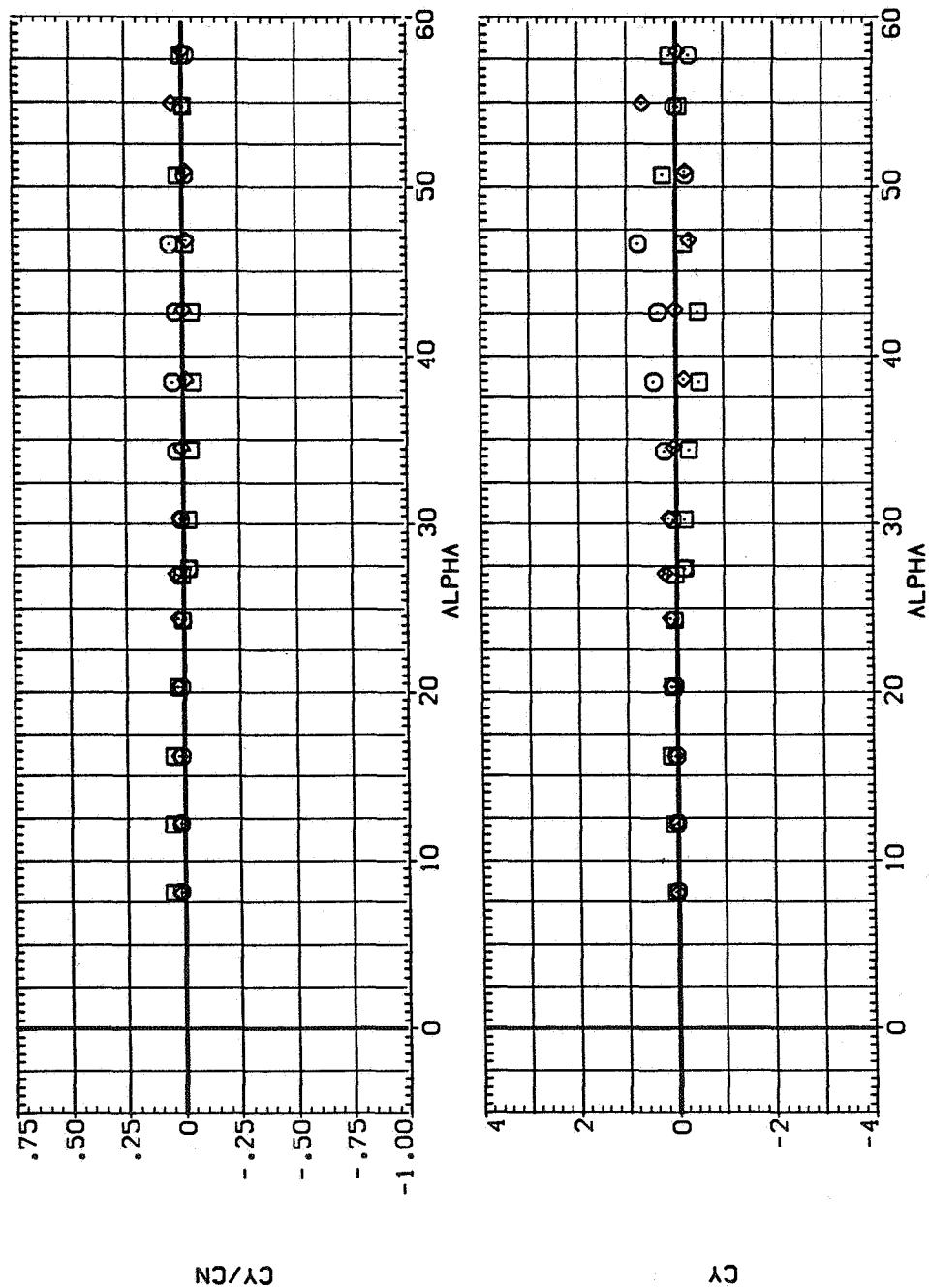
SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 13.— Effect of nose strokes;  $M = 0.6$ ,  $Re = 6.5 \times 10^5$ .

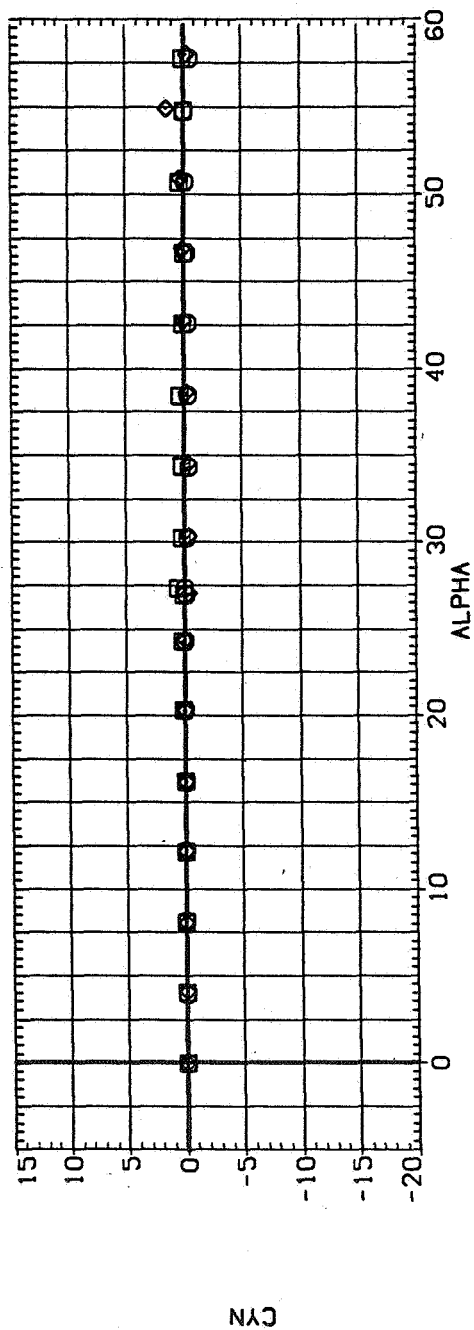
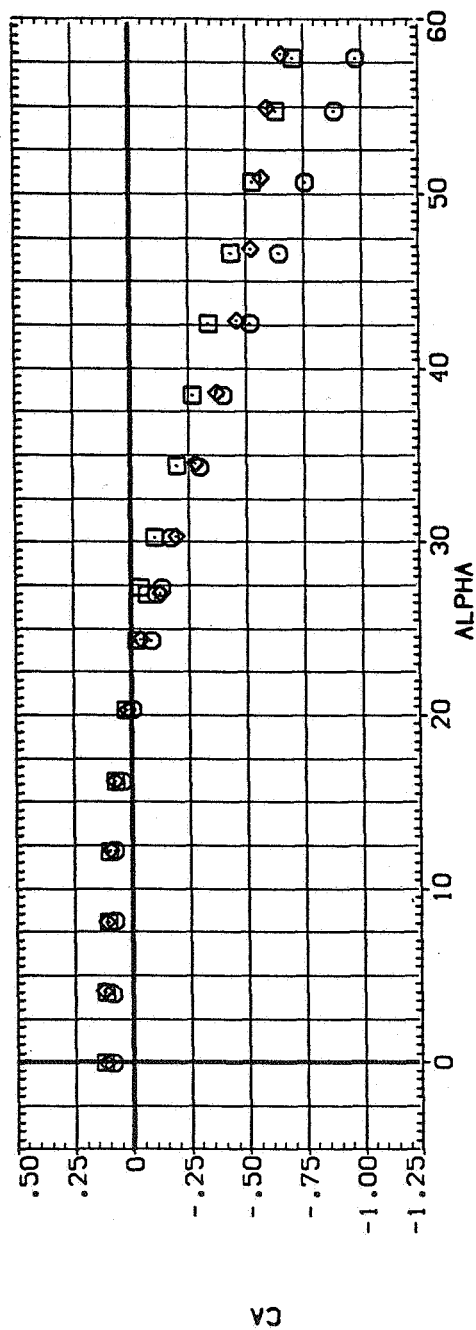
SYMBOL CONFIGURATION DESCRIPTION  
 $\square$  NI CI S  
 $\square$  NS CI S  
 $\diamond$  NS CI S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

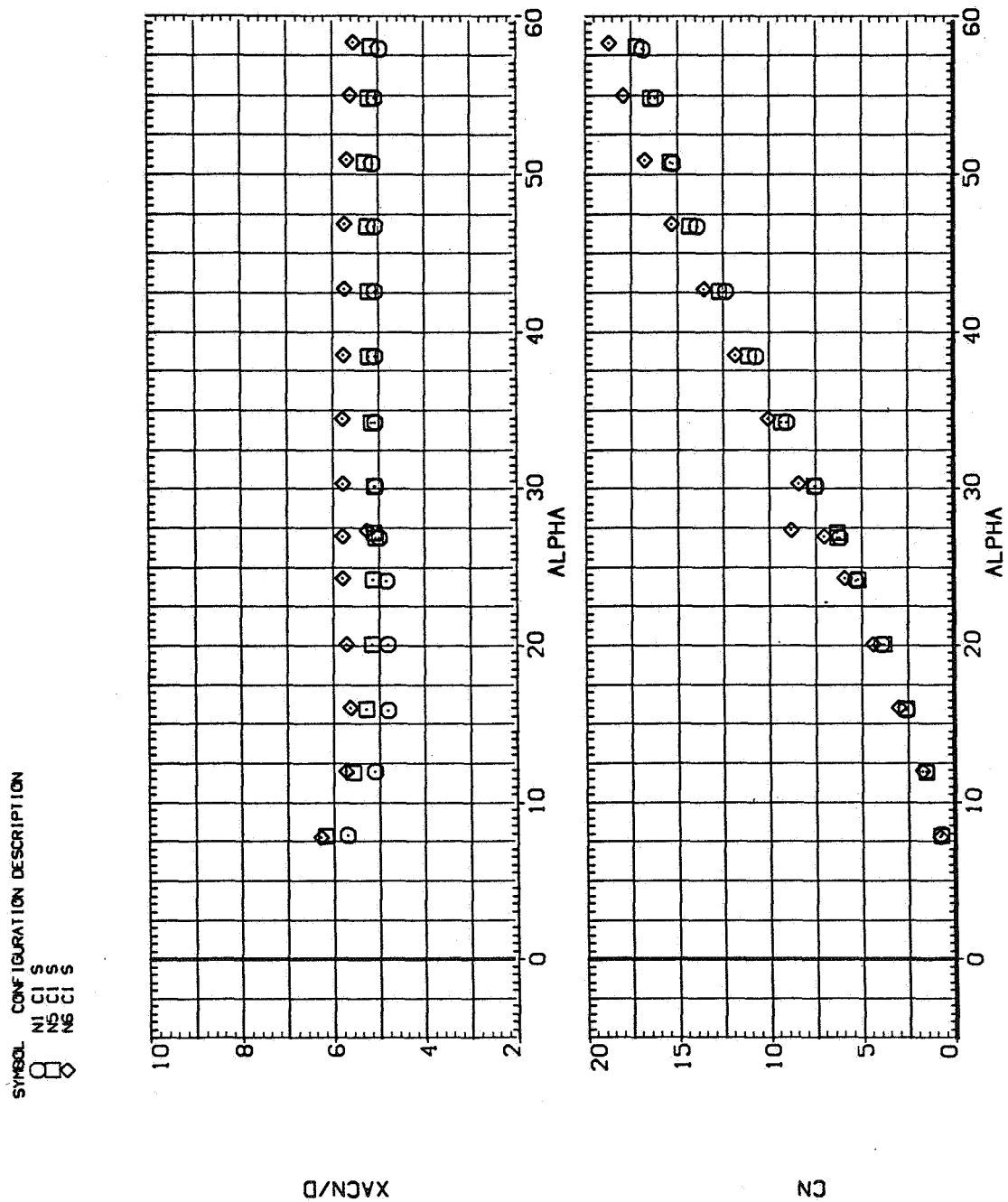
Figure 13.— Continued.

SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .




Figure 13.— Concluded.

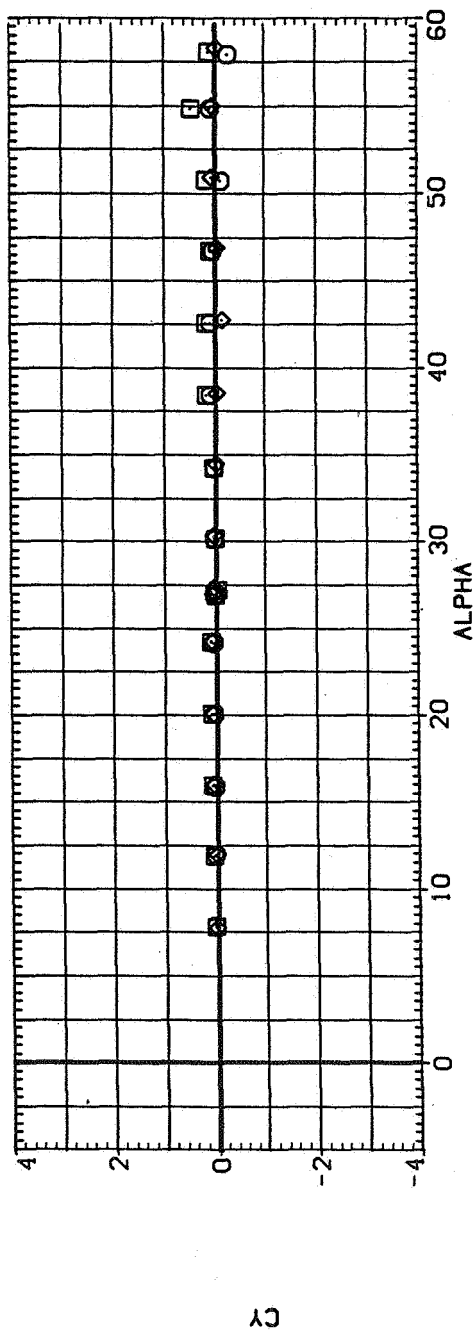
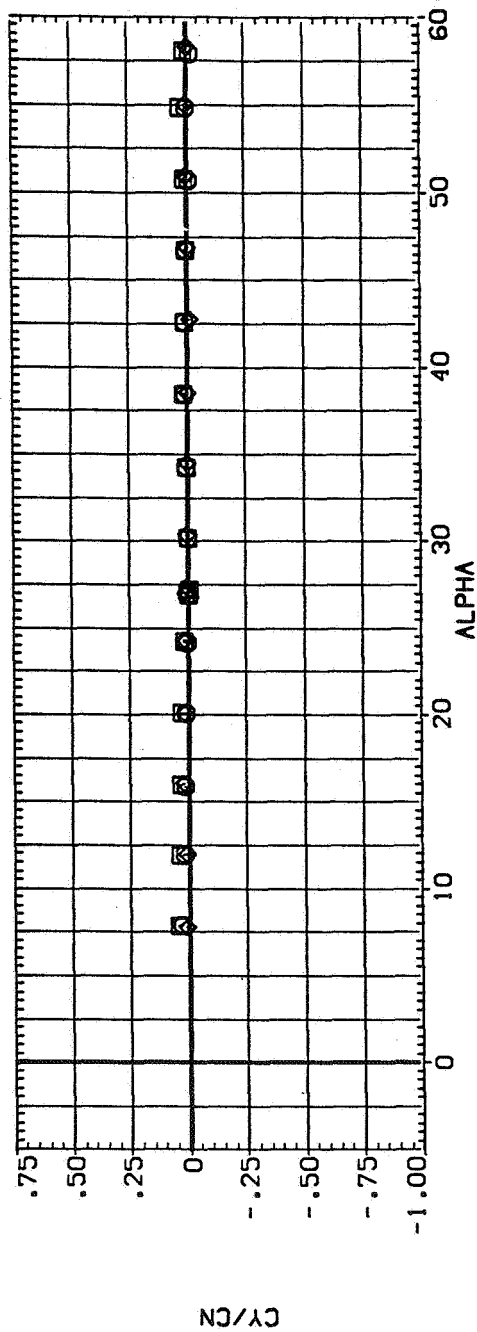


(a)  $x_{ac_N}/d$  and  $C_N$  versus  $\alpha$ .

Figure 14.— Effect of nose strokes;  $M = 0.9$ ,  $Re = 6.5 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

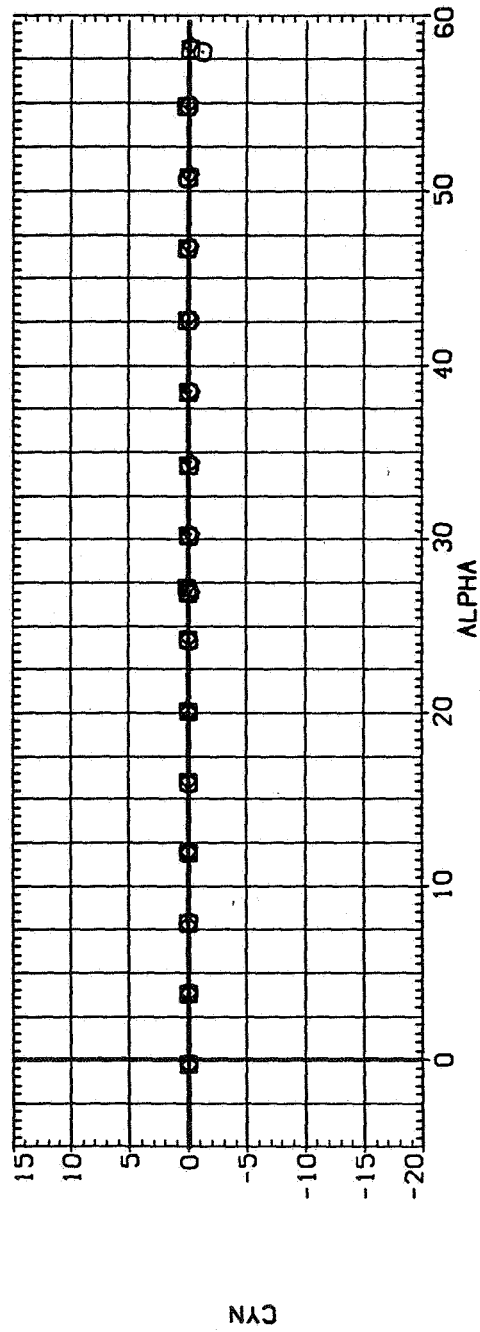
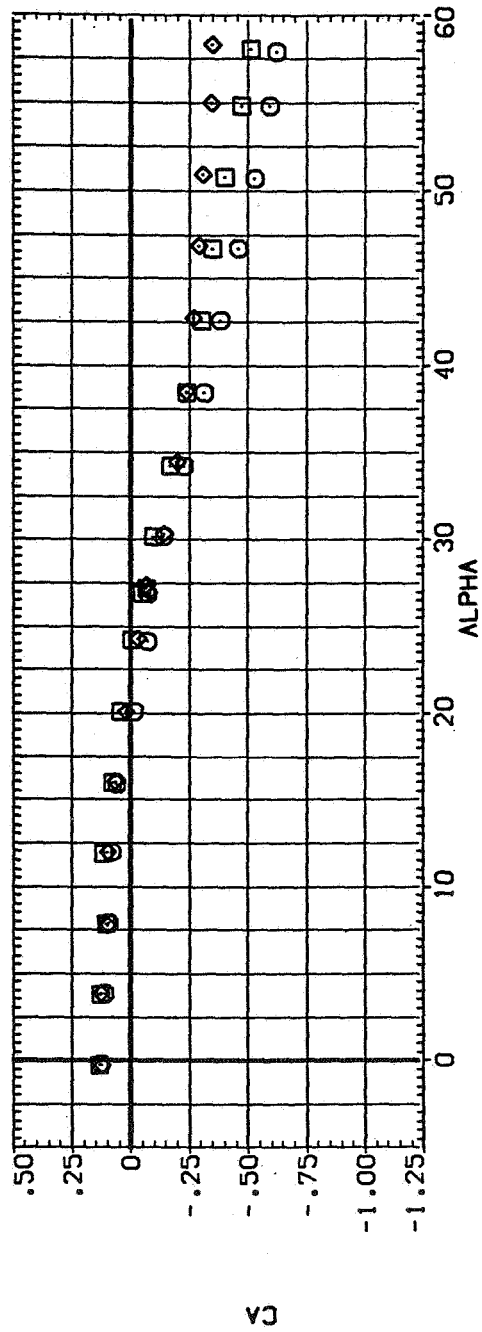
 N1 Cl S  
 N2 Cl S  
 N3 Cl S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 14. — Continued.

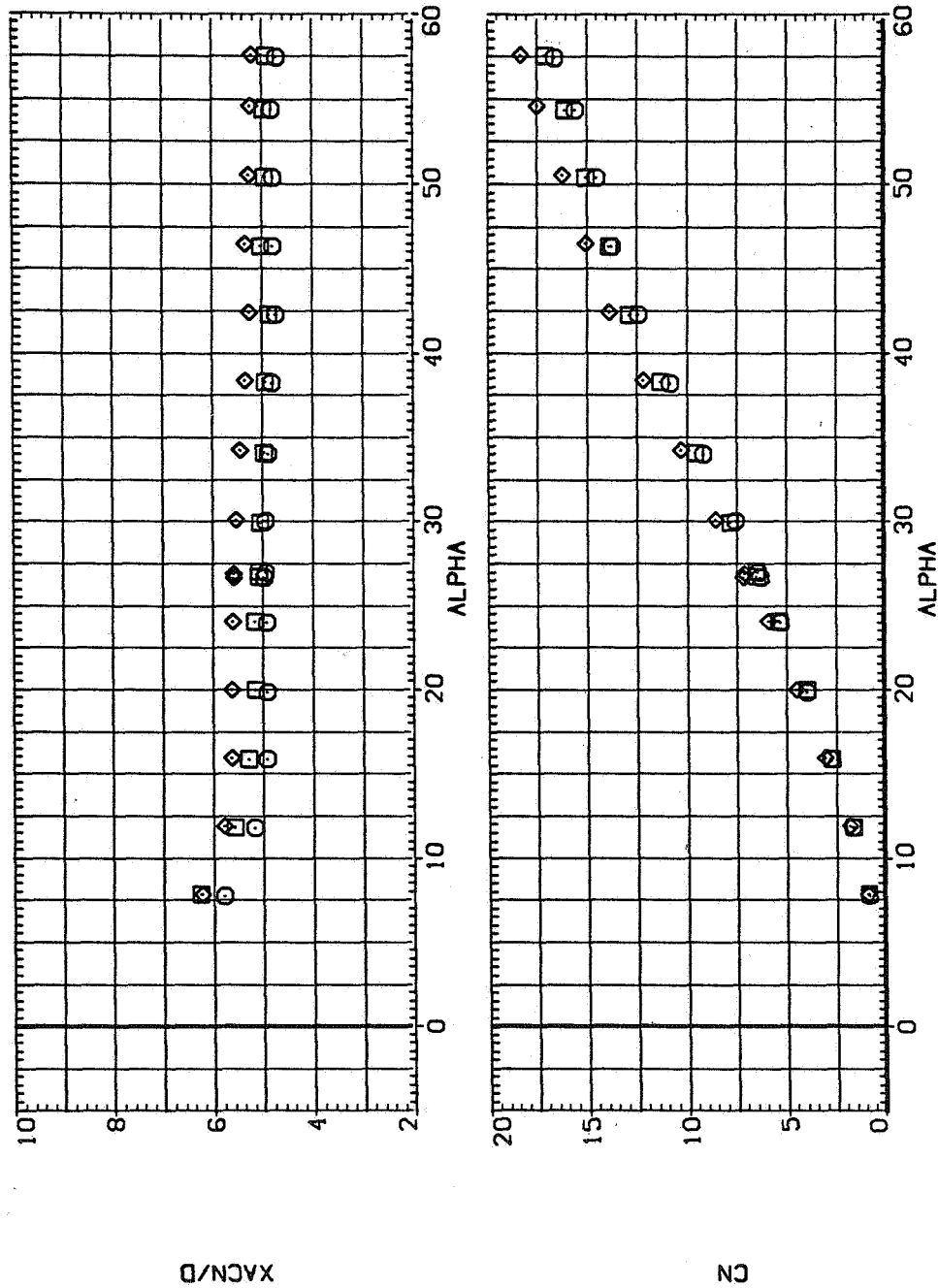
SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S S S  
 NS CI CI S  
 NS



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 14.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S

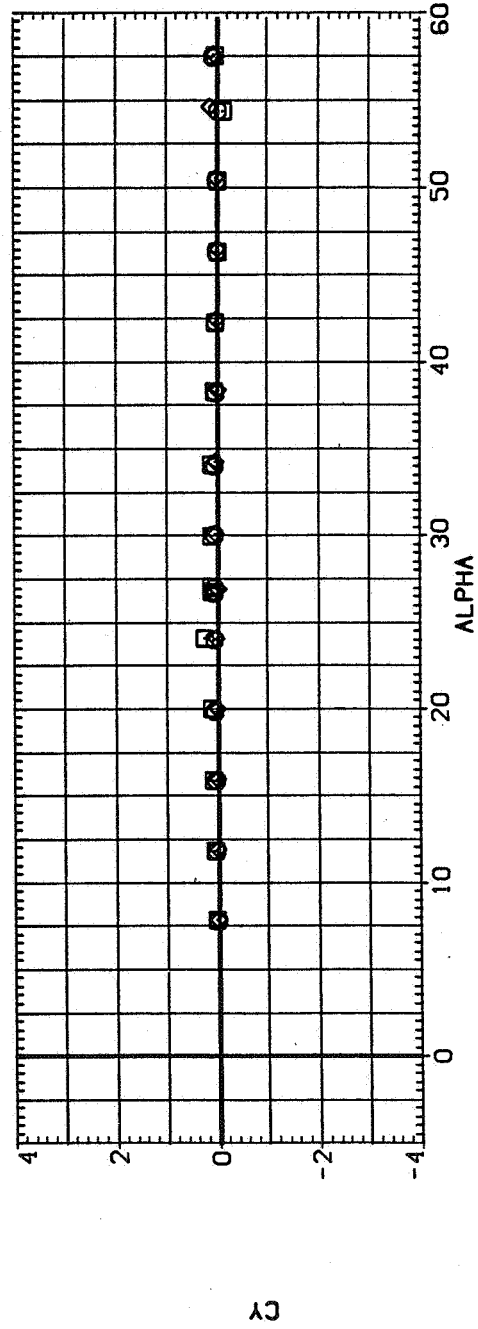
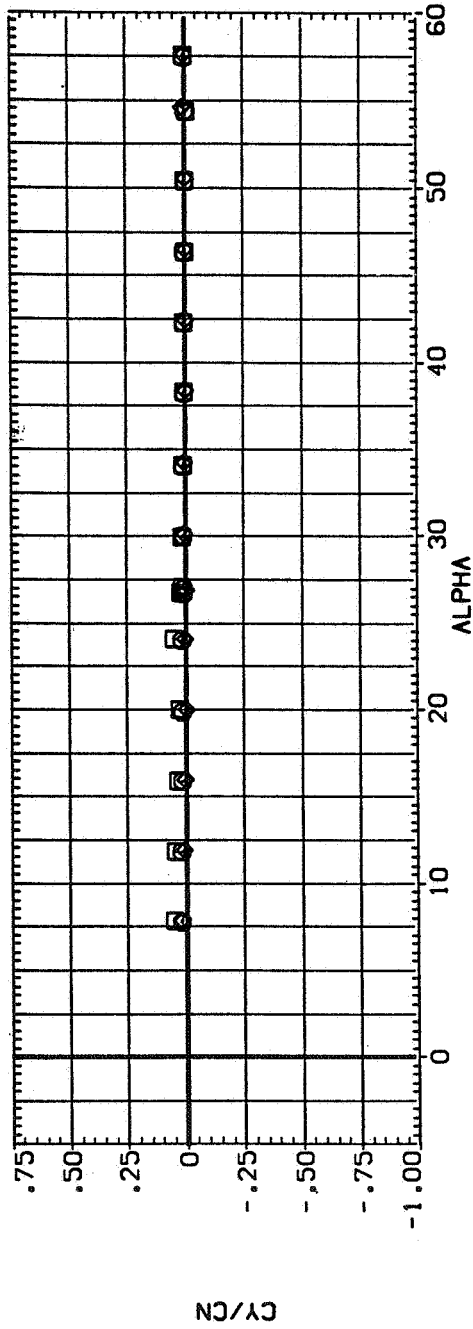


(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 15.— Effect of nose strokes;  $M = 1.2$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

$\square$  Ni  
 $\square$  Cl  
 $\square$  S  
 $\square$  Ni  
 $\square$  Cl  
 $\square$  S

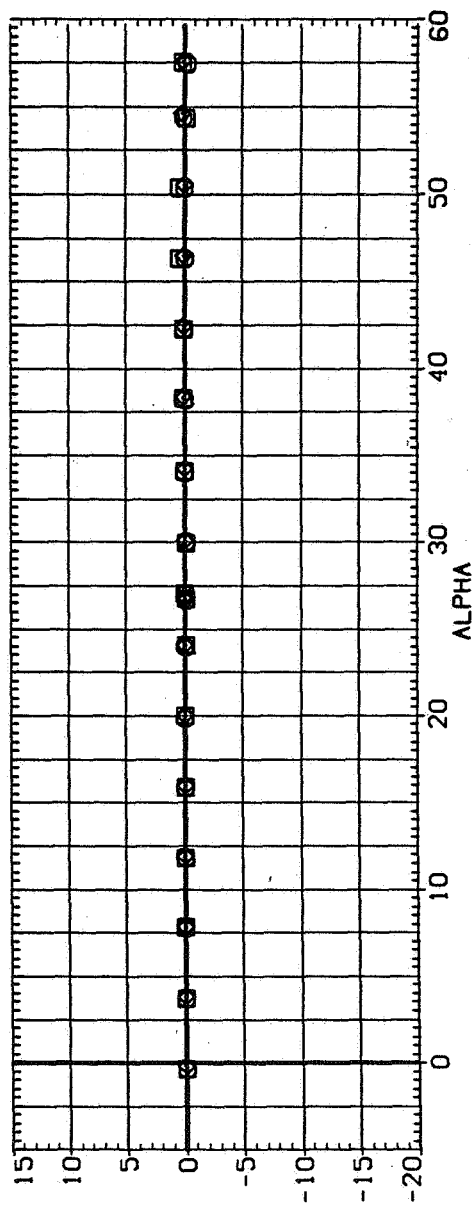
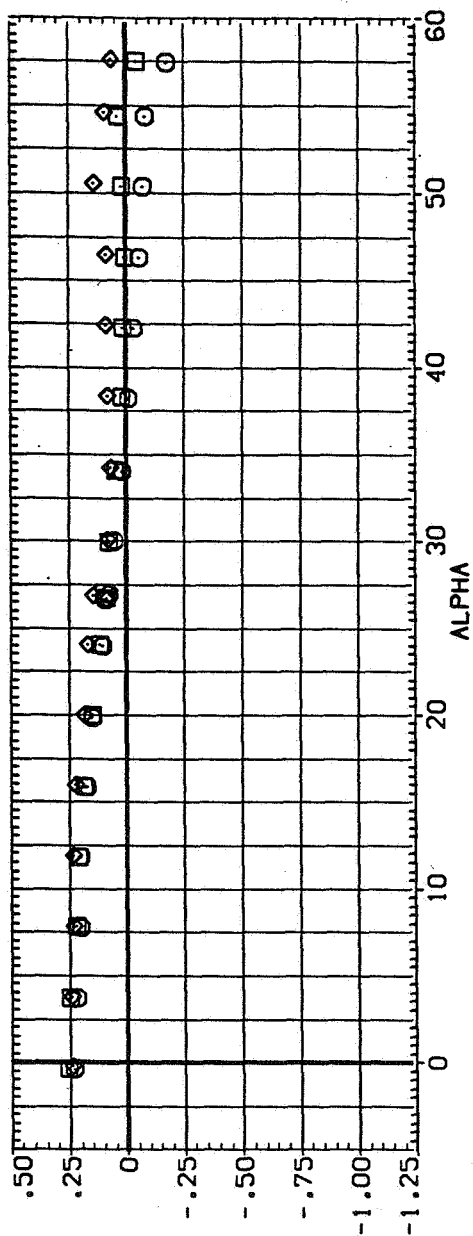


(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 15.— Continued.



SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S

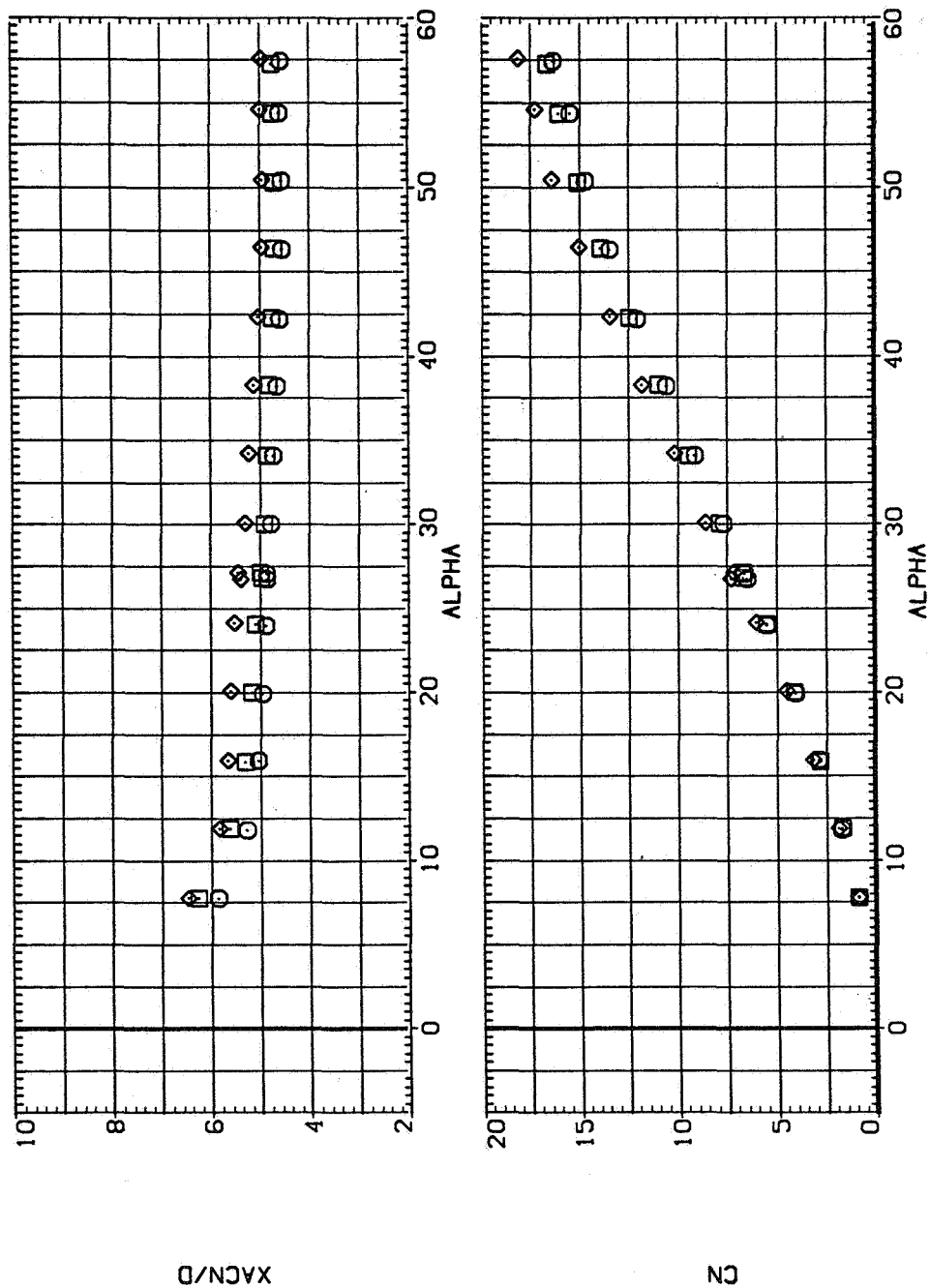


(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 15.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION

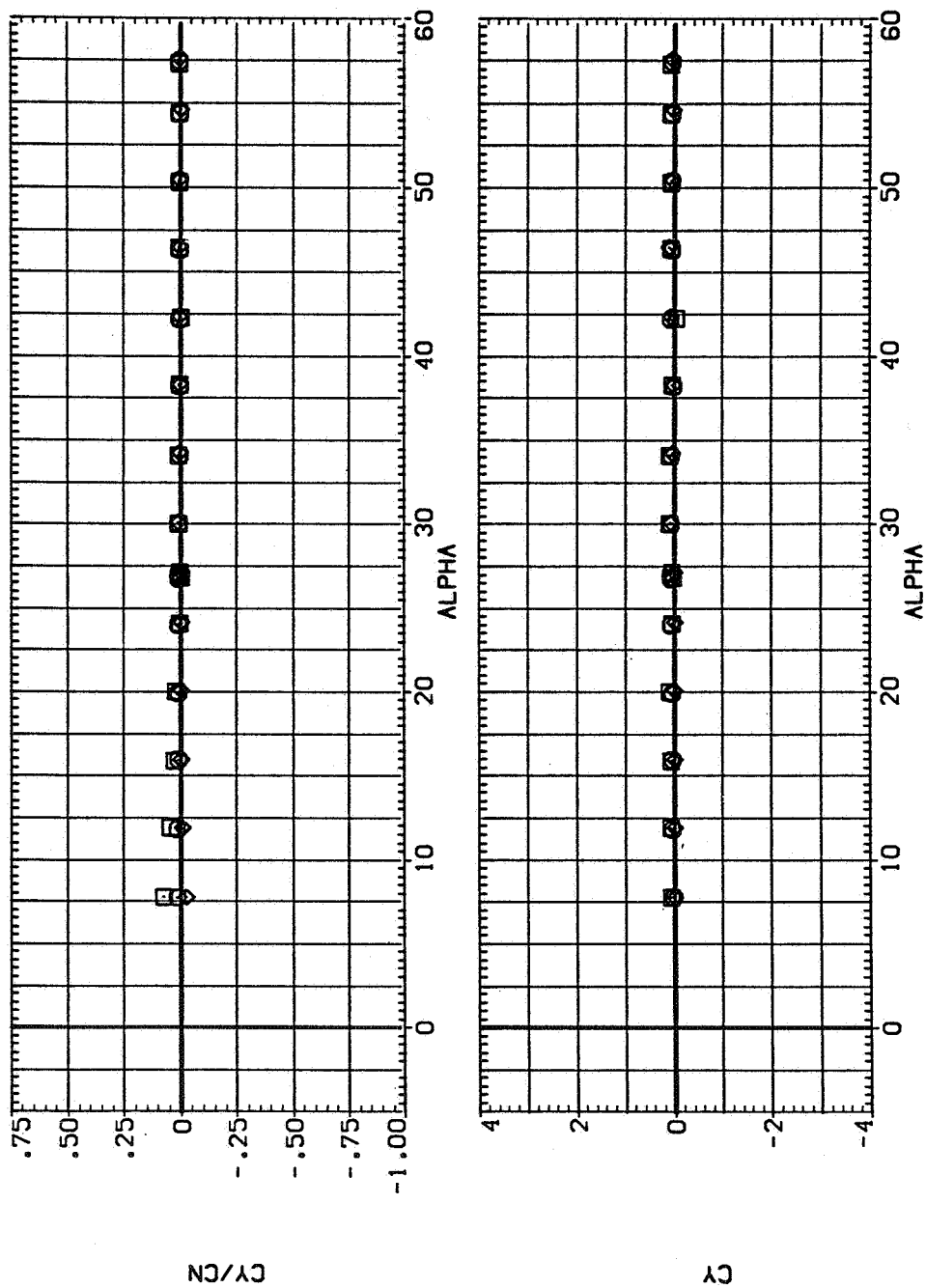
$\diamond$  N  
 $\square$  C  
 $\circ$  C  
 $\circ$  C  
 $\circ$  C  
 $\circ$  S  
 $\circ$  S  
 $\circ$  S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

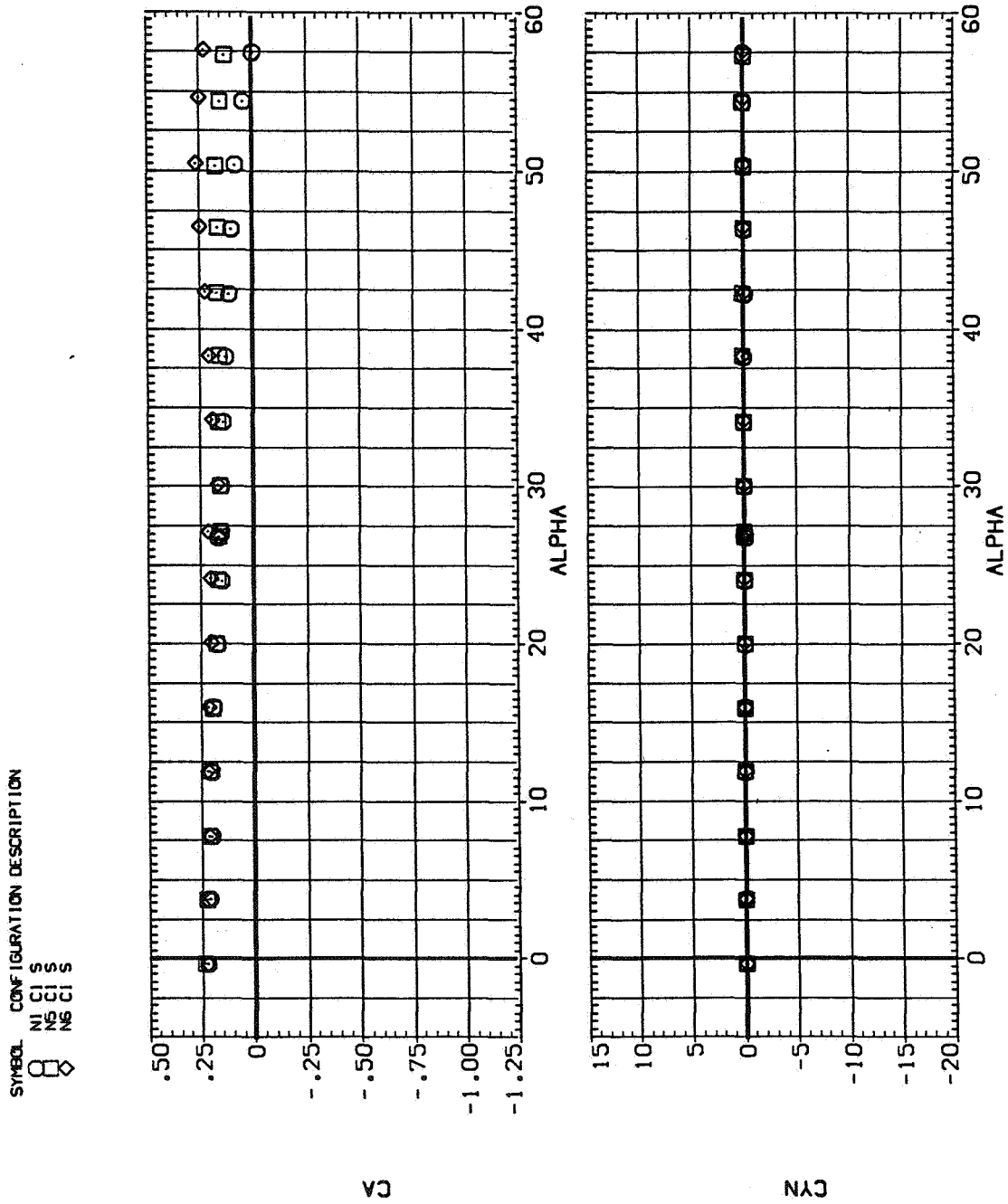
Figure 16.— Effect of nose strokes;  $M = 1.5$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

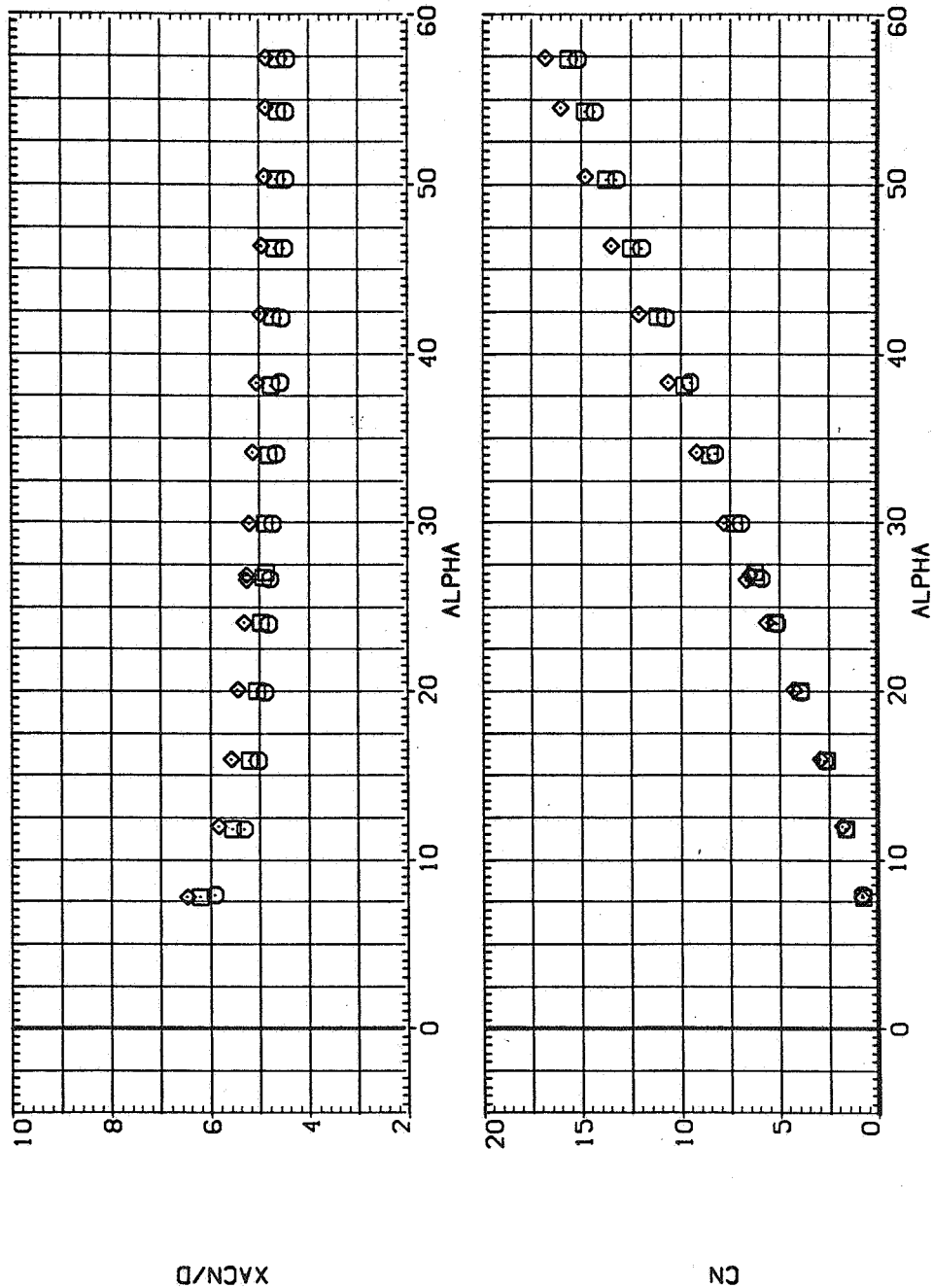
Figure 16.— Continued.



(c)  $C_A$  and  $C_N$  versus  $\alpha$ .

Figure 16.— Concluded.

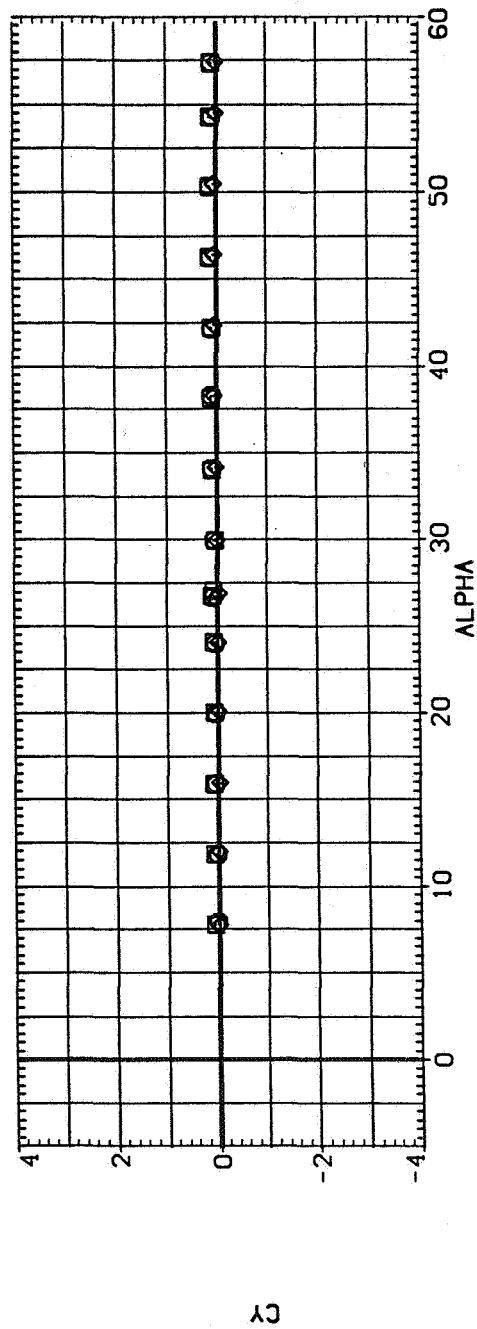
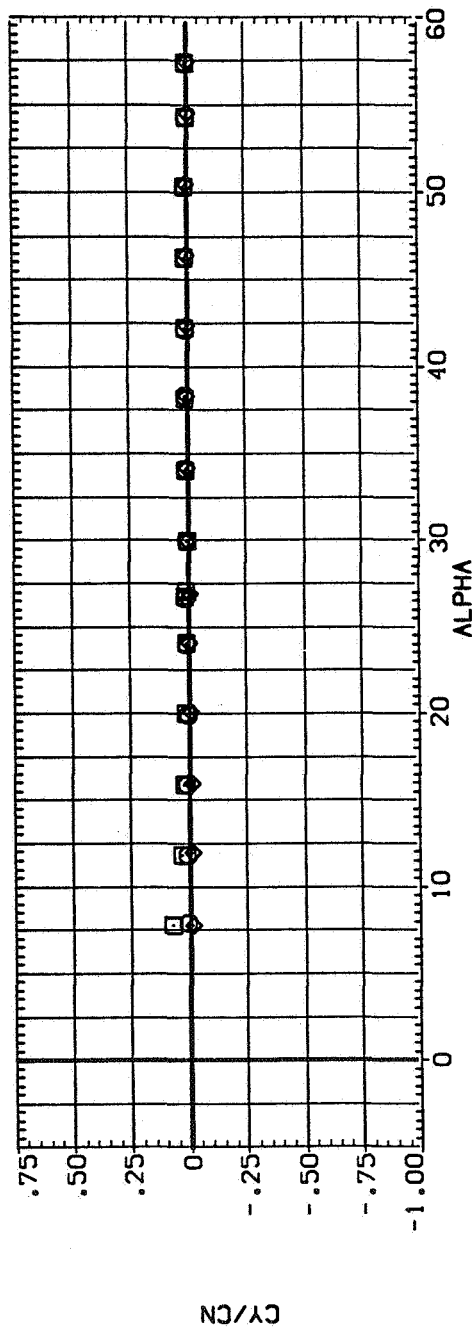
SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 17.— Effect of nose strokes;  $M = 2.0$ ,  $Re = 3.8 \times 10^5$ .

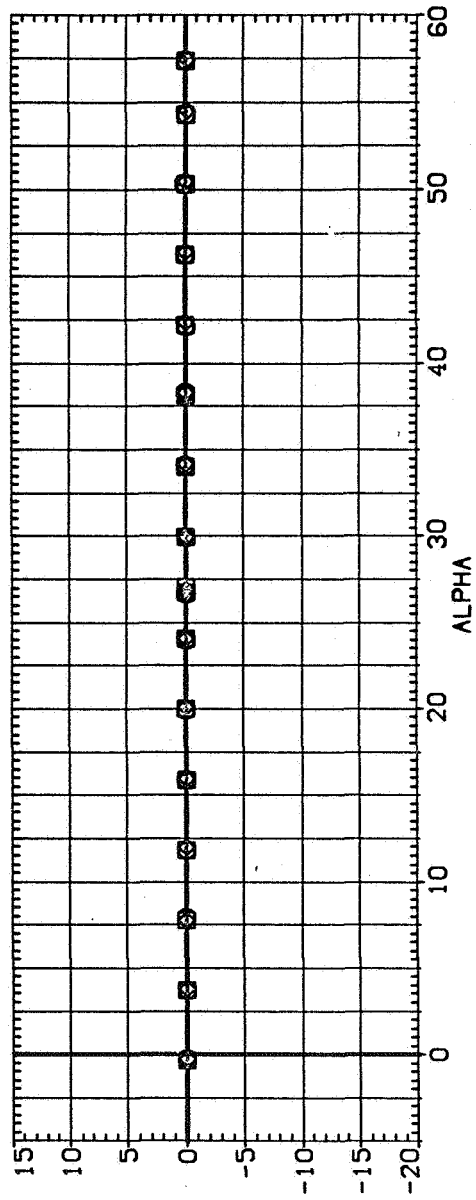
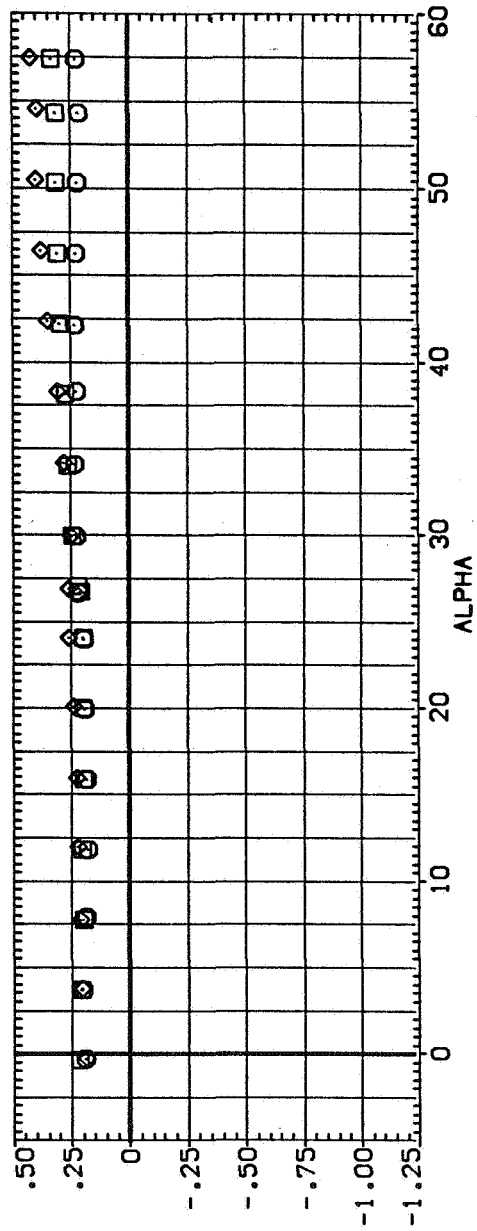
SYMBOL CONFIGURATION DESCRIPTION  
 NI Cl S  
 NS Cl S  
 NS Cl S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 17.— Continued.

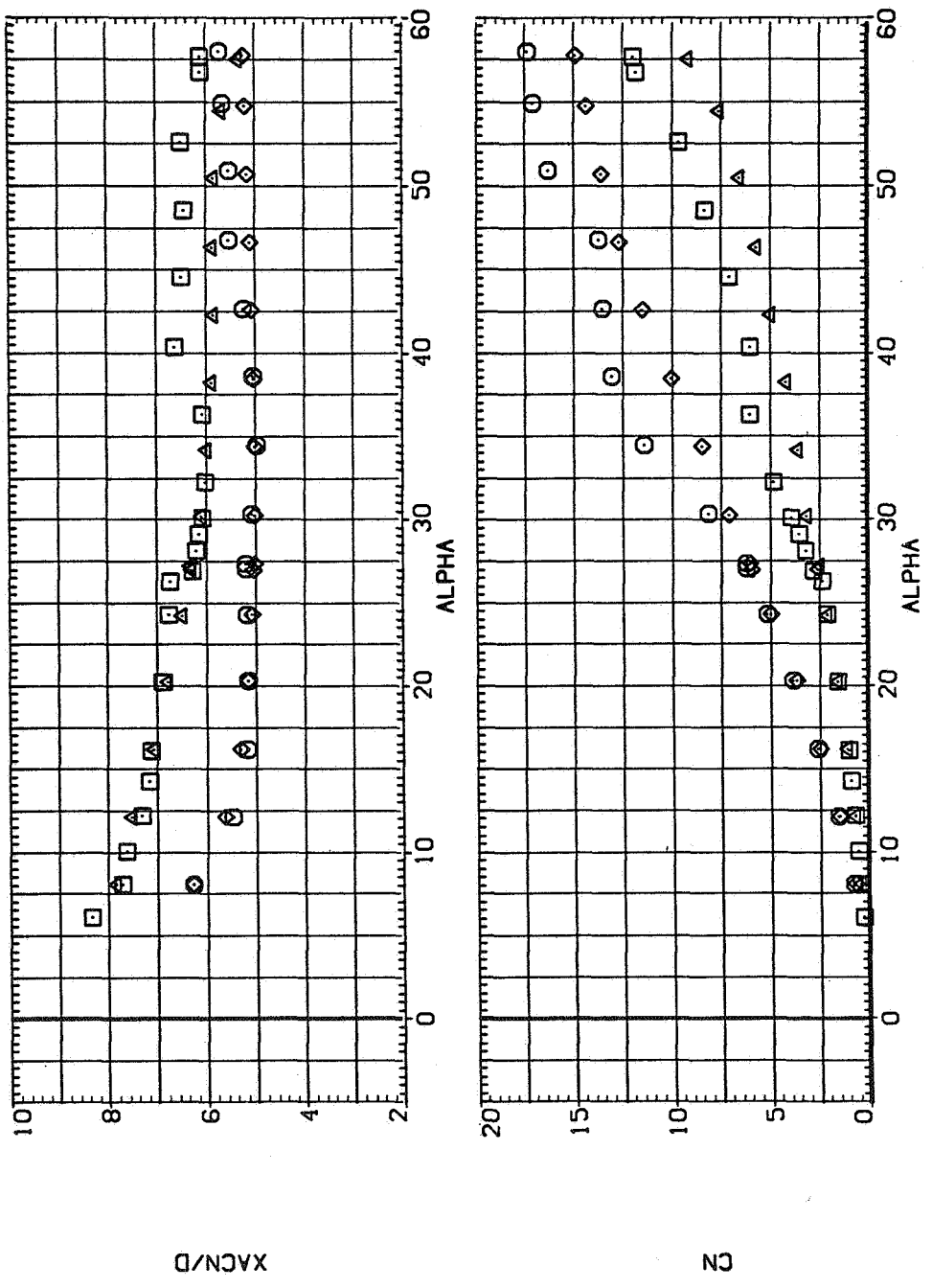
SYMBOL CONFIGURATION DESCRIPTION  
 NI CI S  
 NS CI S  
 NS CI S



(c)  $C_A$  and  $C_\eta$  versus  $\alpha$ .

Figure 17.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION  
 $\square$  NS C1 S  
 $\circ$  NS C1 S  
 $\triangle$  NS C1 S  
 $\diamond$  NS C1 S



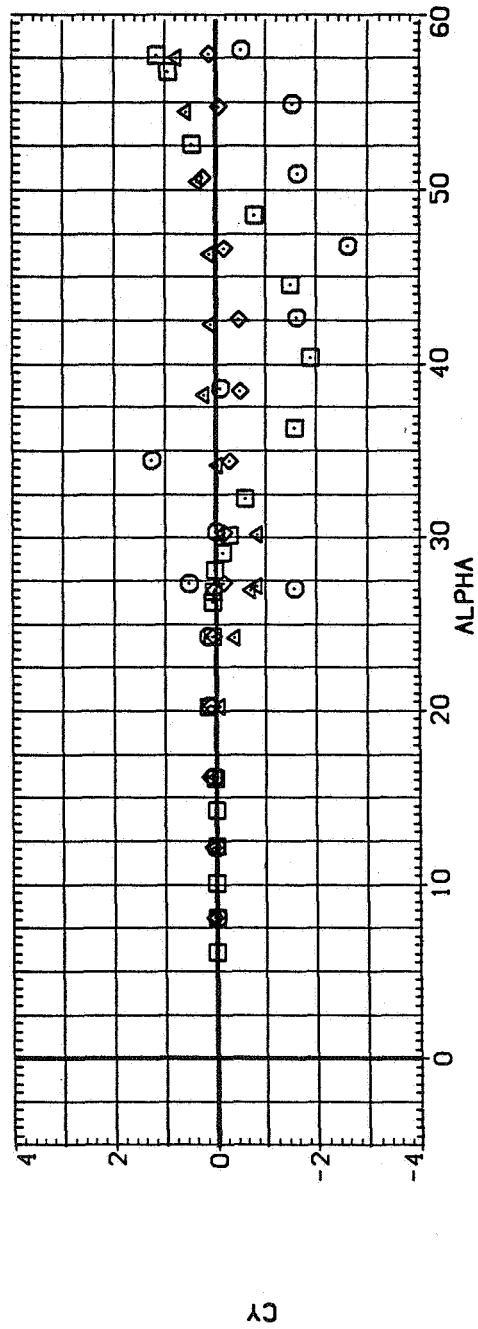
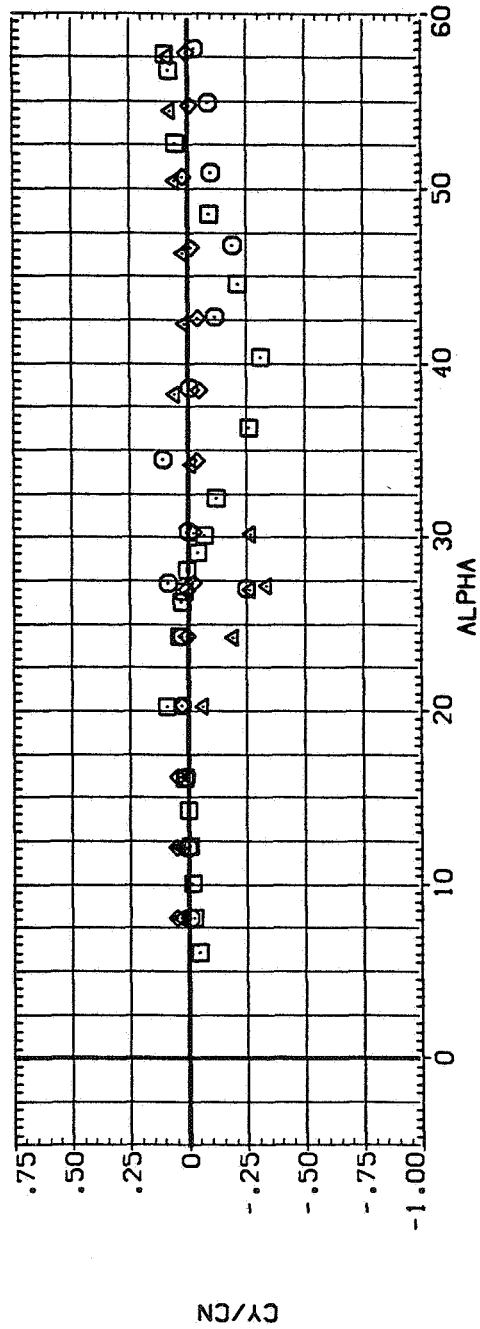
(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 18.— Effect of removing strakes from body,  $M = 0.6$ ,  $Re = 6.5 \times 10^5$ .



SYMBOL CONFIGURATION DESCRIPTION

$\square$  N3 C1 S  
 $\triangle$  N3 C1 S  
 $\circ$  N5 C1 S  
 $\times$  N5 C1 S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 18.— Continued.

SYMBOL CONFIGURATION DESCRIPTION

$\square$  NG CI S  
 $\square$  NS CI S  
 $\square$  NS CI

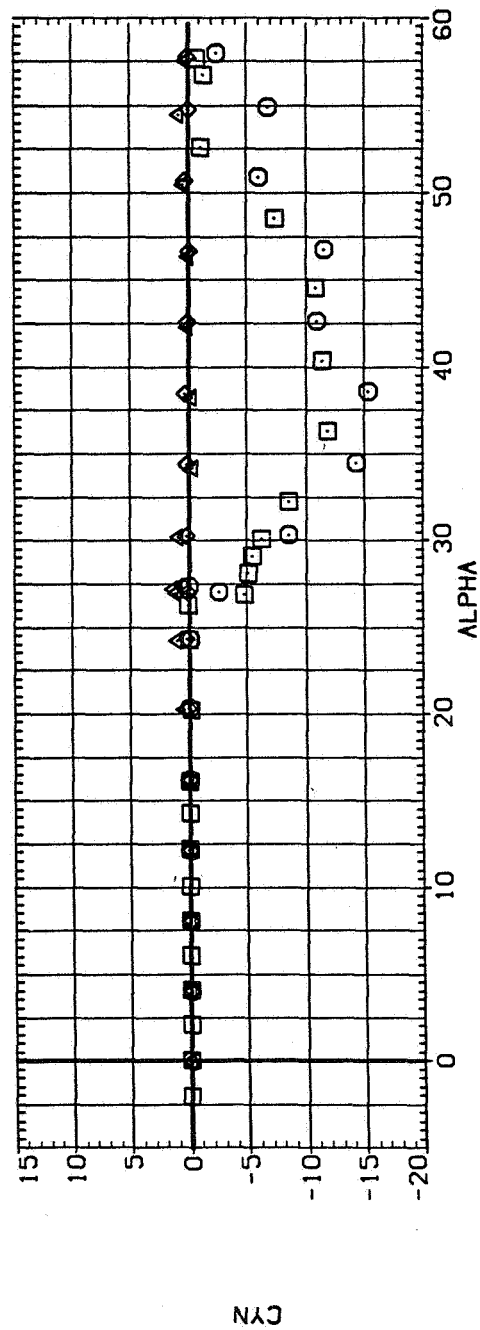
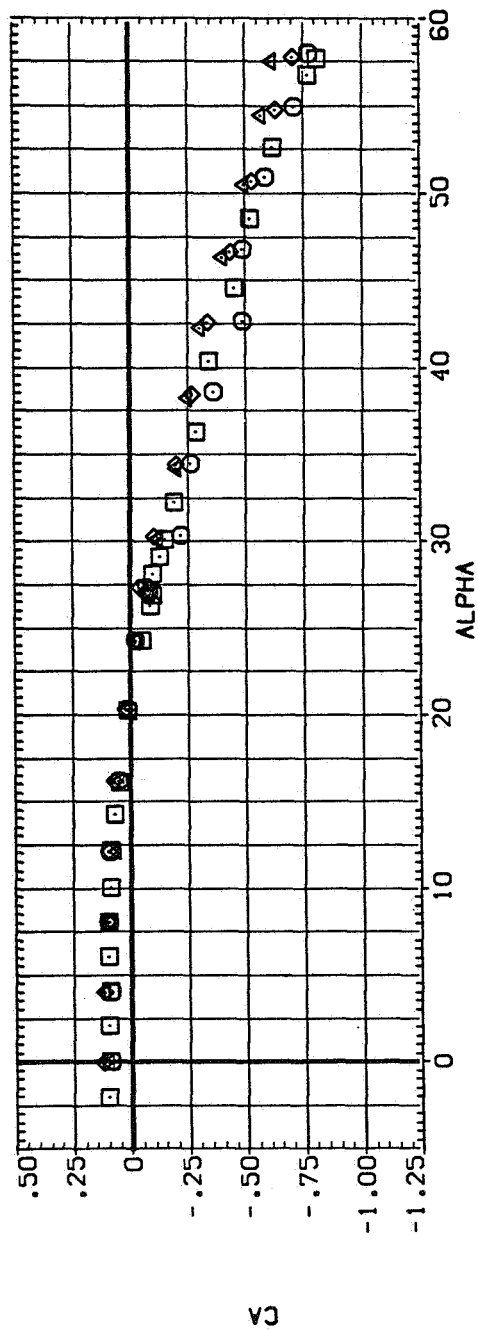
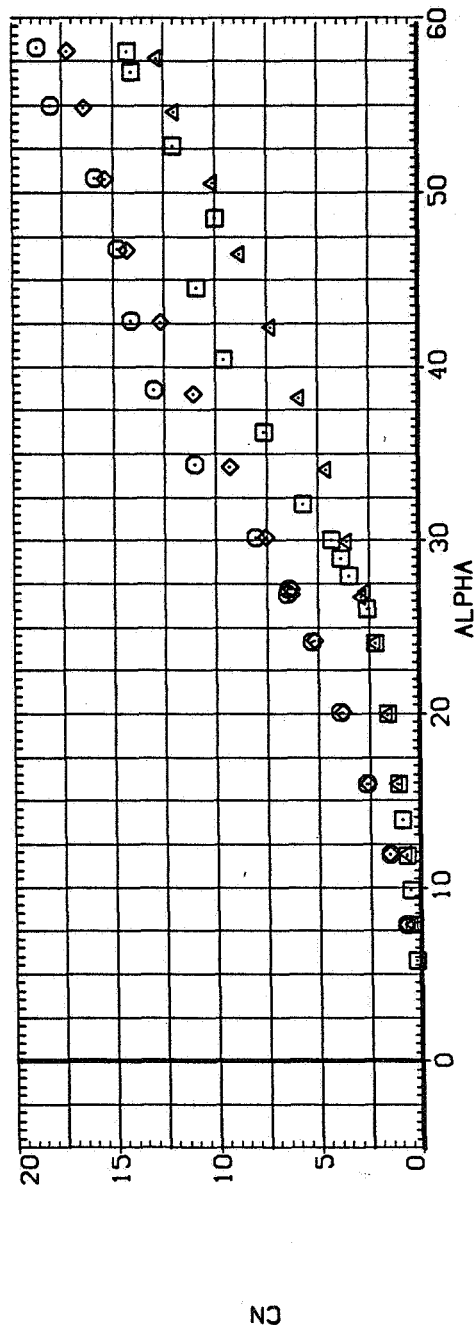
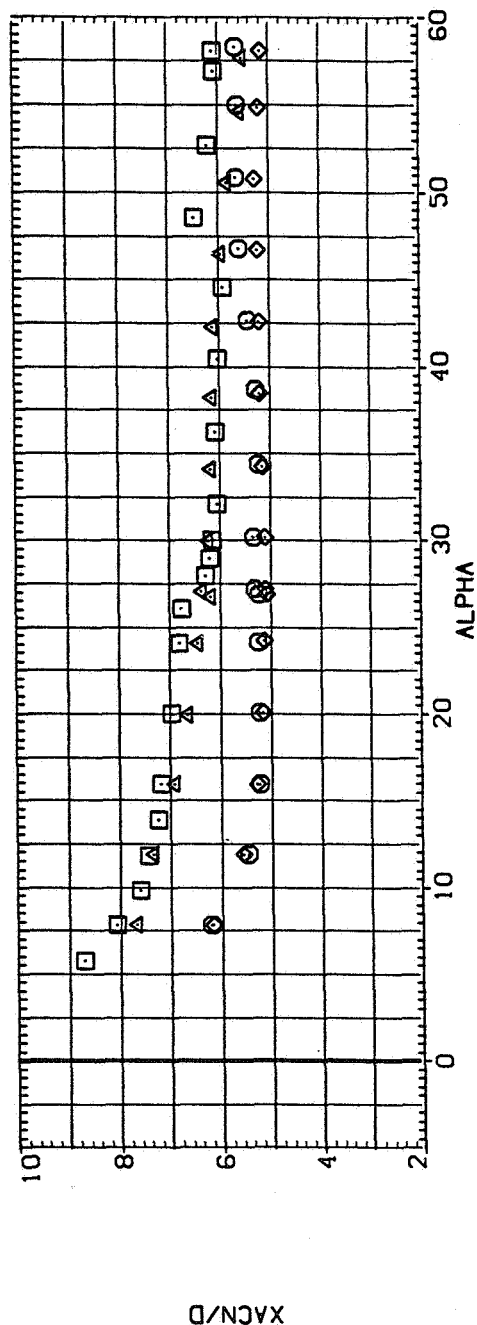
(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 18.— Concluded.

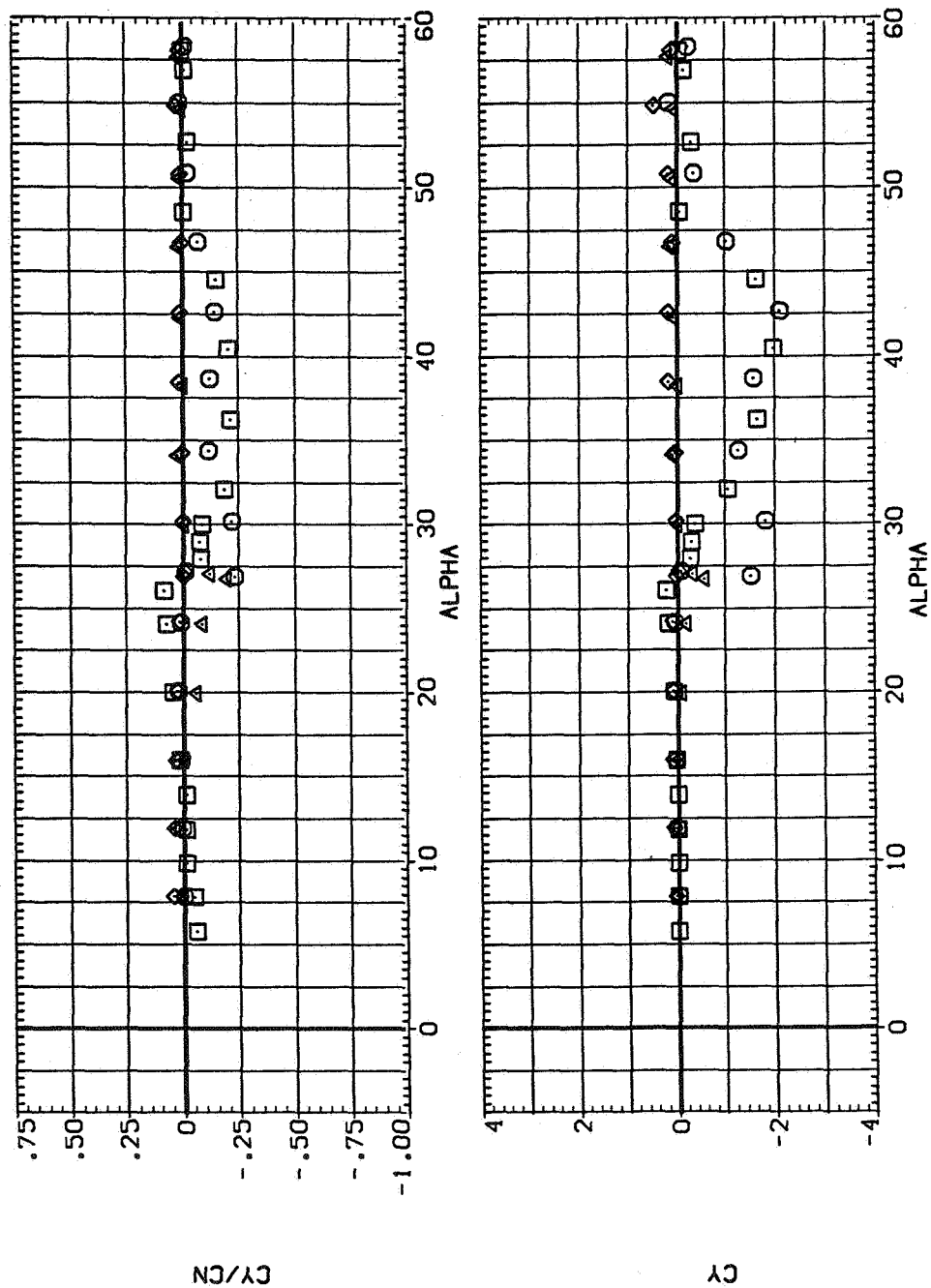
SYMBOL CONFIGURATION DESCRIPTION  
 N3 CI S  
 N3 CI S  
 N5 CI S  
 N5 CI S



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 19.— Effect of removing strakes from body;  $M = 0.9$ ,  $Re = 6.5 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 $\square$  N3 Cl S  
 $\triangle$  N3 Cl S  
 $\circ$  N5 Cl S  
 $\times$  N5 Cl

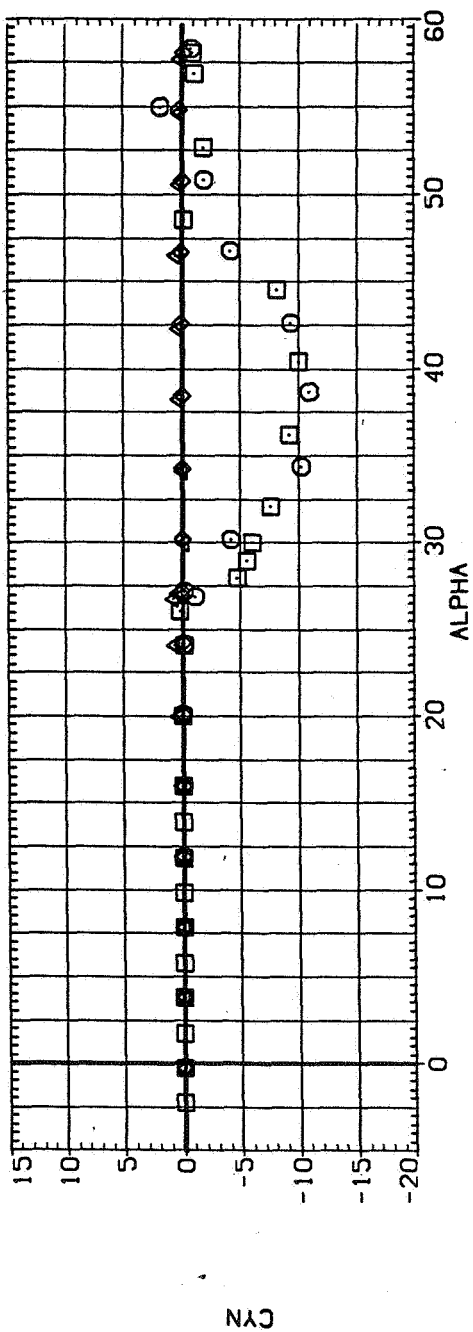
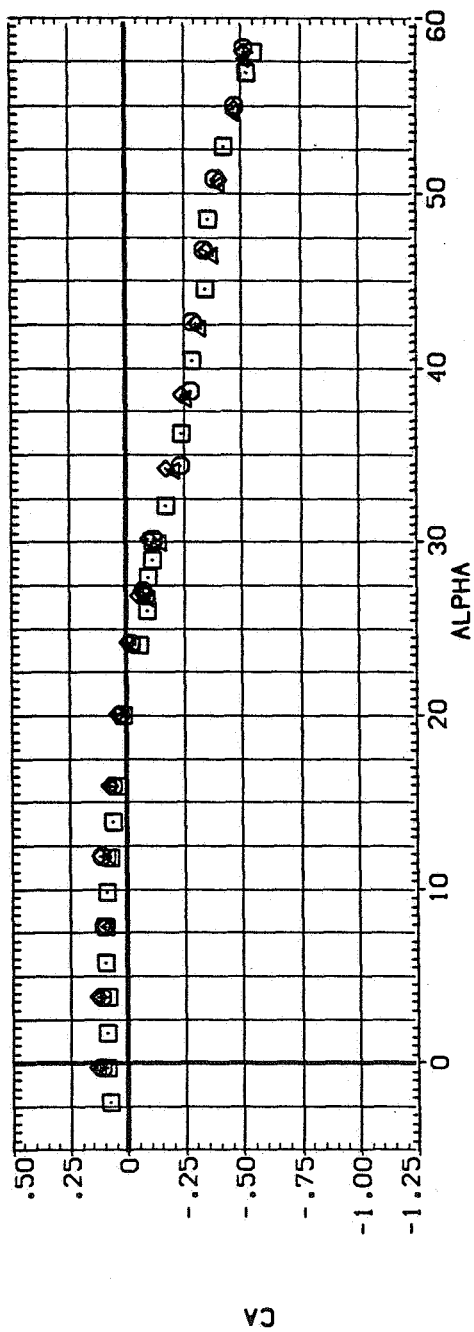


(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 19. — Continued.

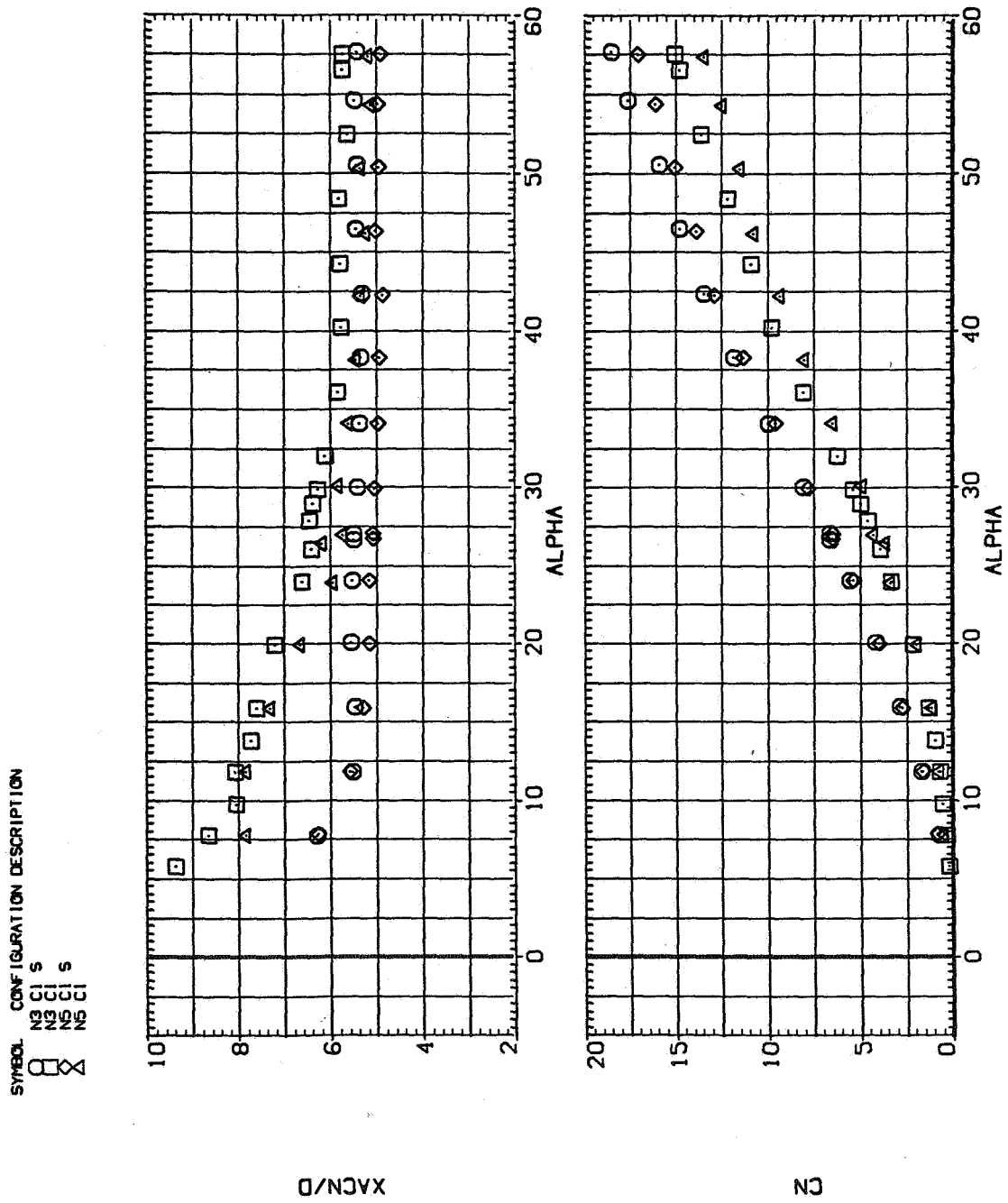
SYMBOL CONFIGURATION DESCRIPTION

$\square$  N3 Cl S  
 $\square$  N3 Cl S  
 $\square$  N5 Cl S  
 $\square$  N5 Cl S



(c)  $C_A$  and  $C_{\eta}$  versus  $\alpha$ .




Figure 19.— Concluded.

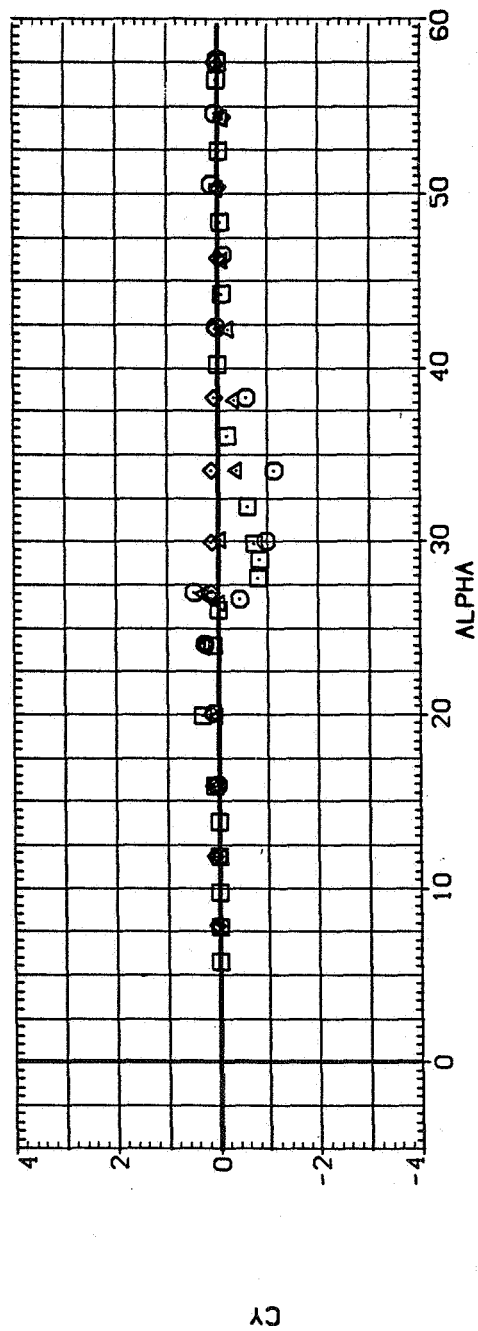
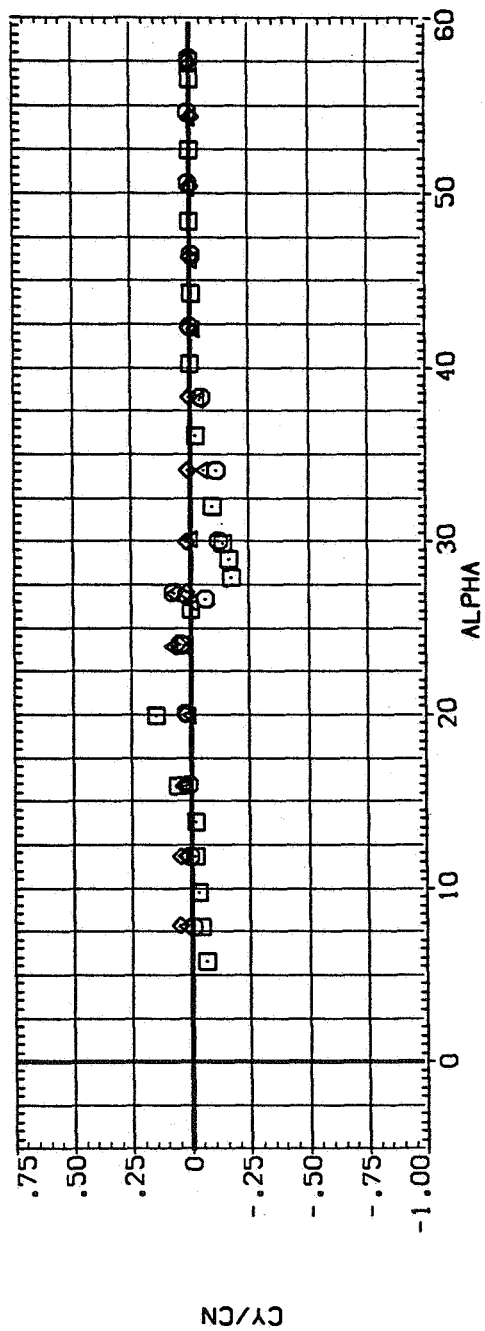


(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 20.— Effect of removing strakes from body;  $M = 1.2$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

	N3 Cl S
	N3 Cl S
	N2 Cl S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 20. - Continued.

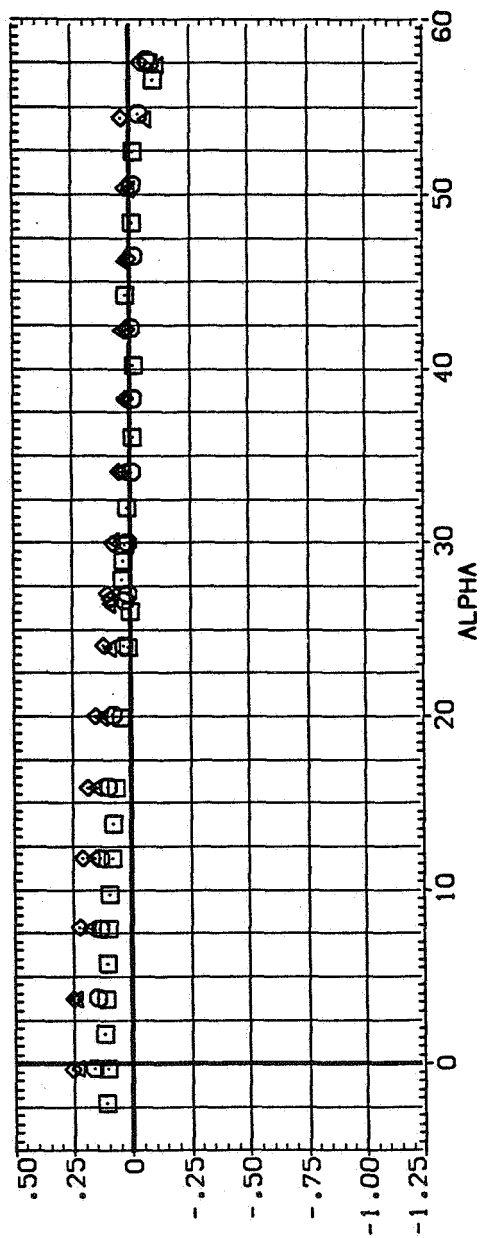
SYMBOL CONFIGURATION DESCRIPTION

N3 C1 S

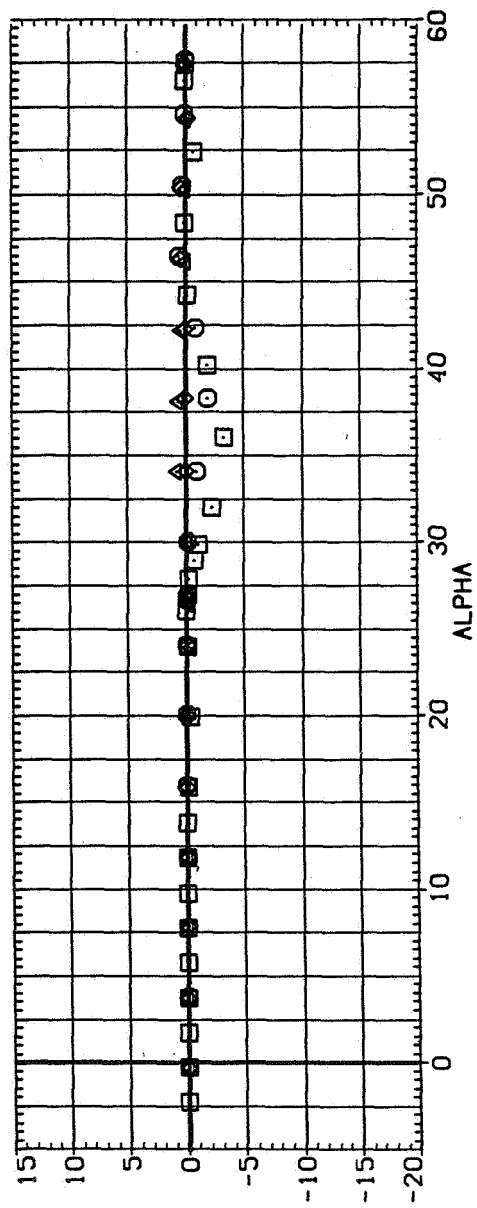
N3 C1 S

N5 C1 S

N5 C1 S



CA



CYN

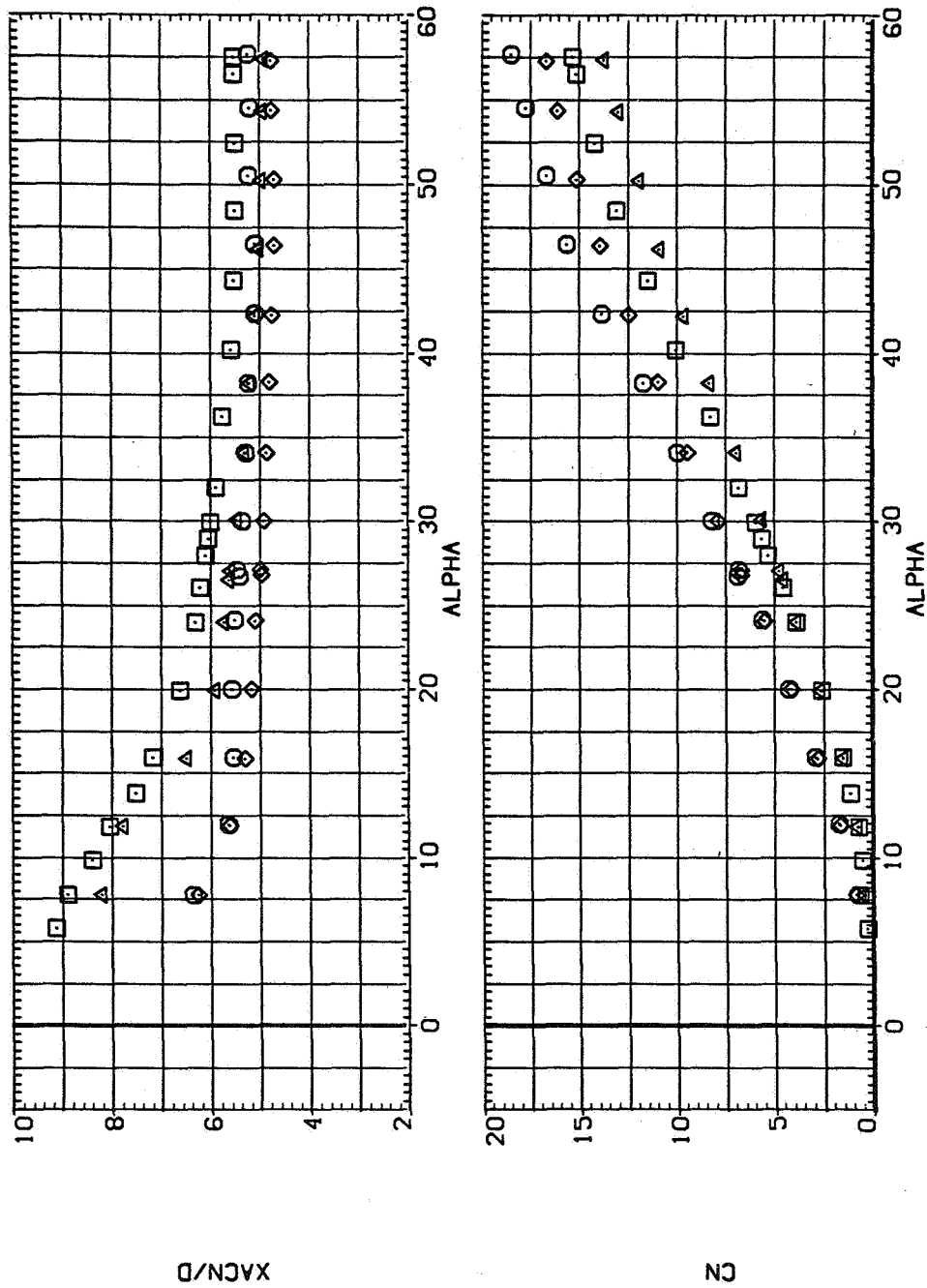
(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 20.— Concluded.



SYMBOL CONFIGURATION DESCRIPTION

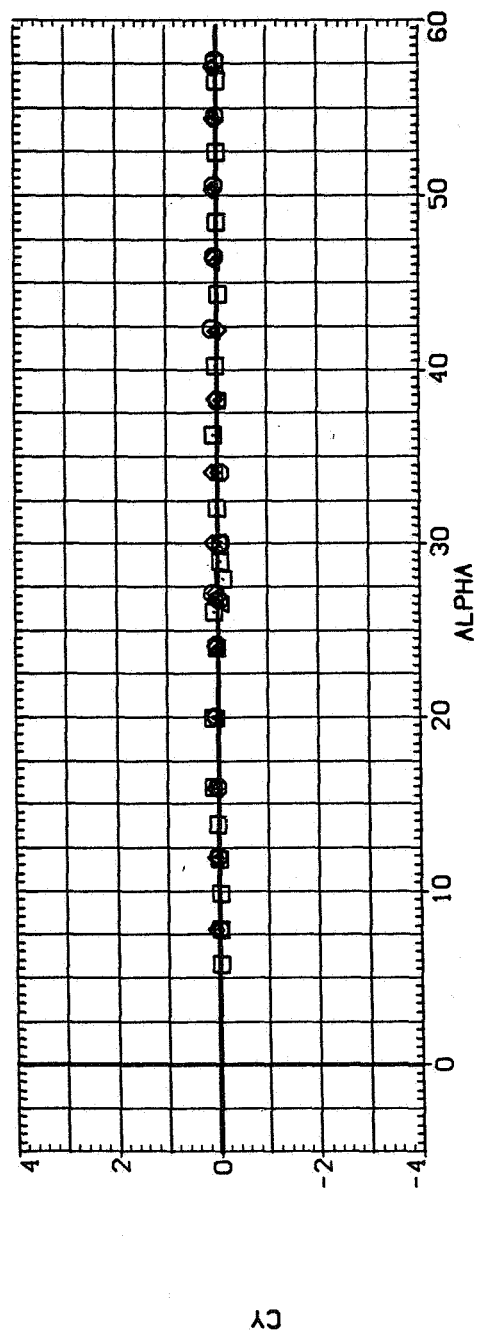
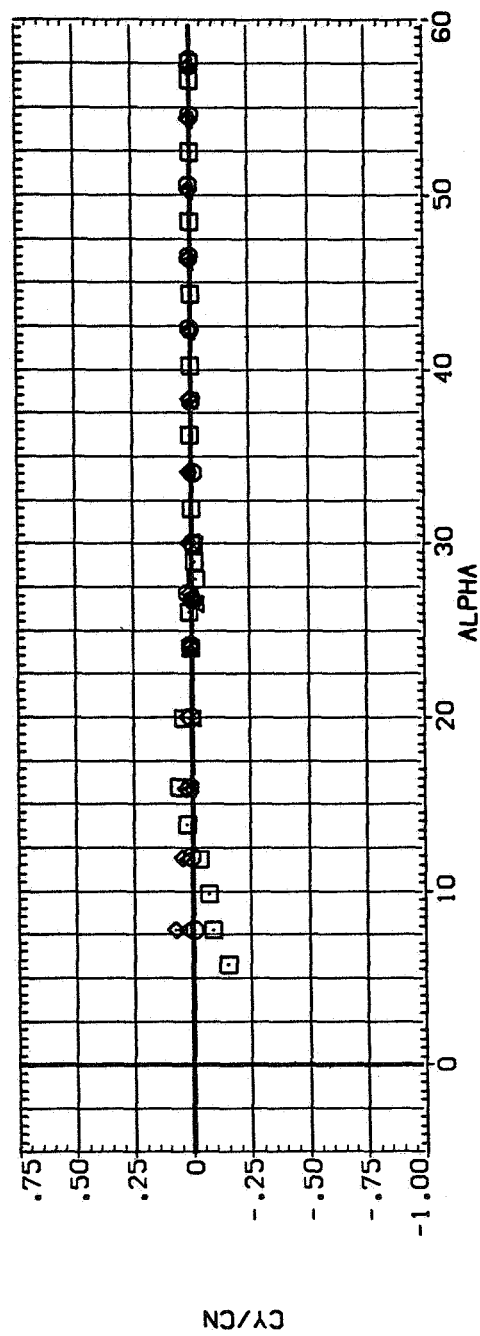
$\square$  N3 C1 S  
 $\triangle$  N3 C1 S  
 $\diamond$  N5 C1 S  
 $\times$  N5 C1



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 21.— Effect of removing strakes from body;  $M = 1.5$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION  
 N3 C1 S  
 N3 C1 S  
 N3 C1 S  
 N3 C1 S

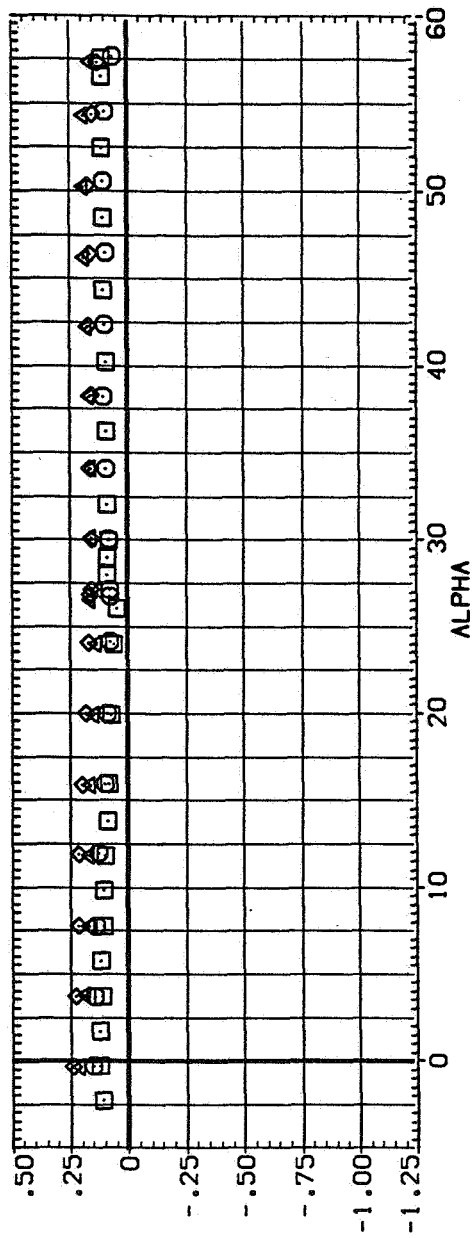


(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

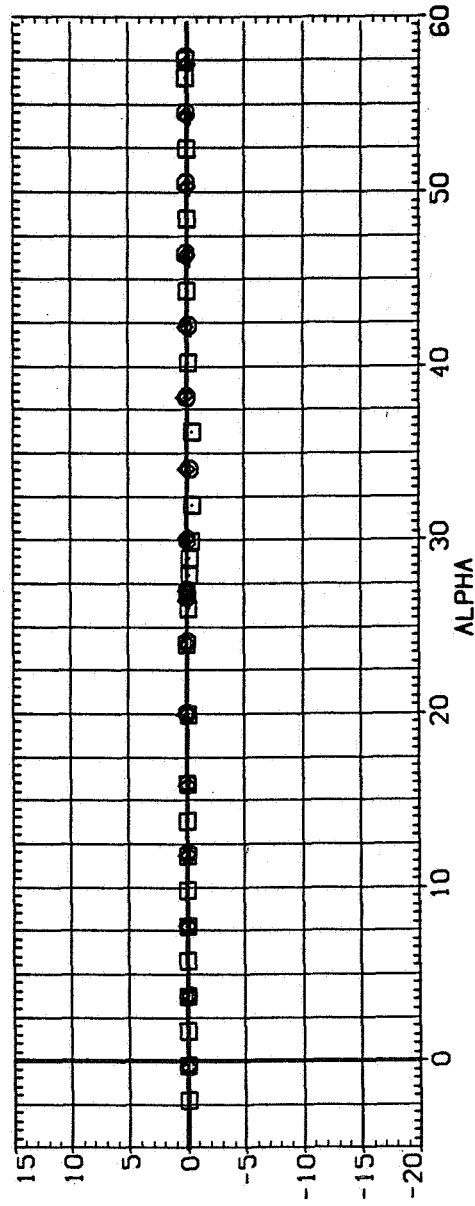
Figure 21.— Continued.

SYMBOL CONFIGURATION DESCRIPTION

$\square$  N3 Cl S  
 $\square$  N3 Cl  
 $\square$  N5 Cl S  
 $\square$  N5 Cl



CA

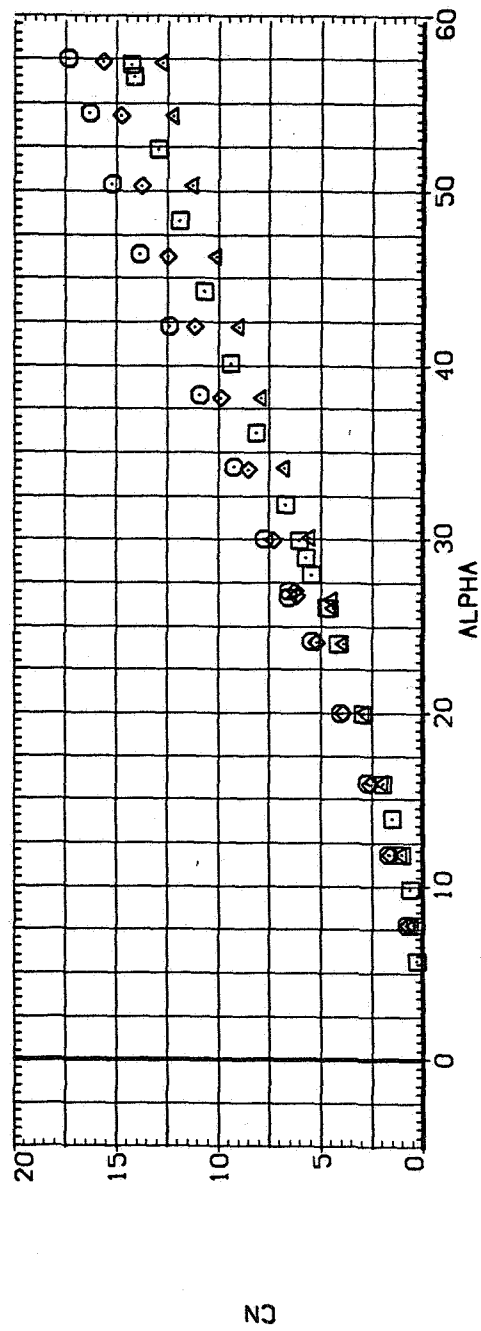
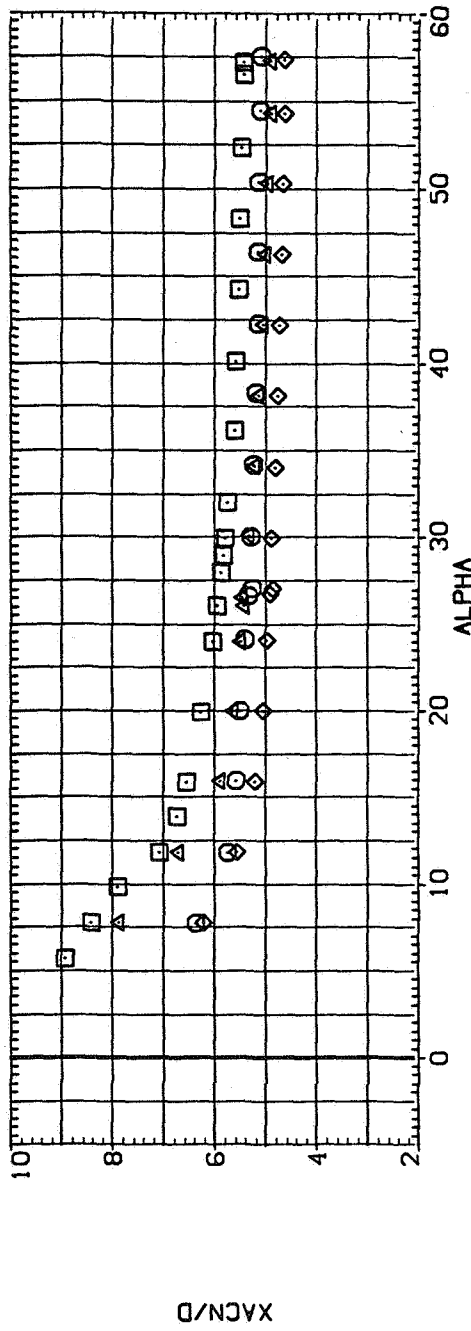


CYN

(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 21.— Concluded.

SYMBOL CONFIGURATION DESCRIPTION  
 □ NS C1 S  
 ◇ NS C1 S  
 △ NS C1 S  
 ○ NS C1 S

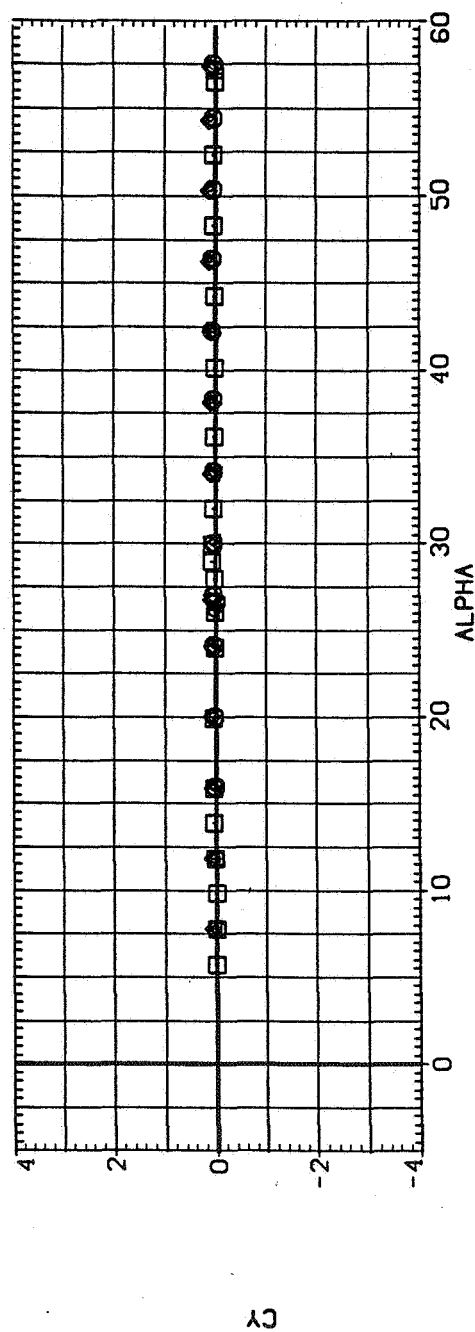
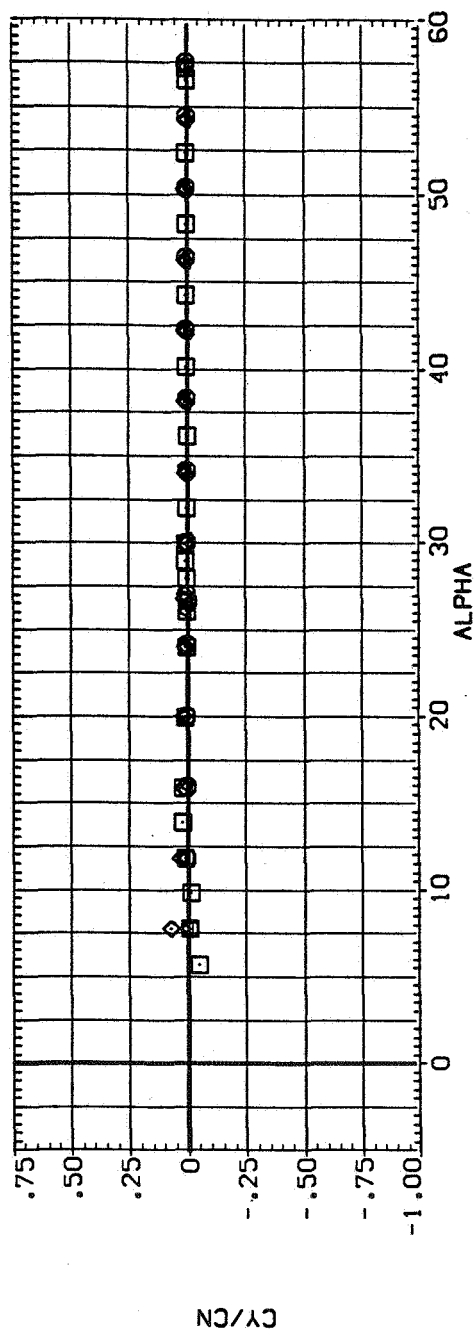


(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 22.— Effect of removing strakes from body;  $M = 2.0$ ,  $Re = 3.8 \times 10^5$ .

SYMBOL CONFIGURATION DESCRIPTION

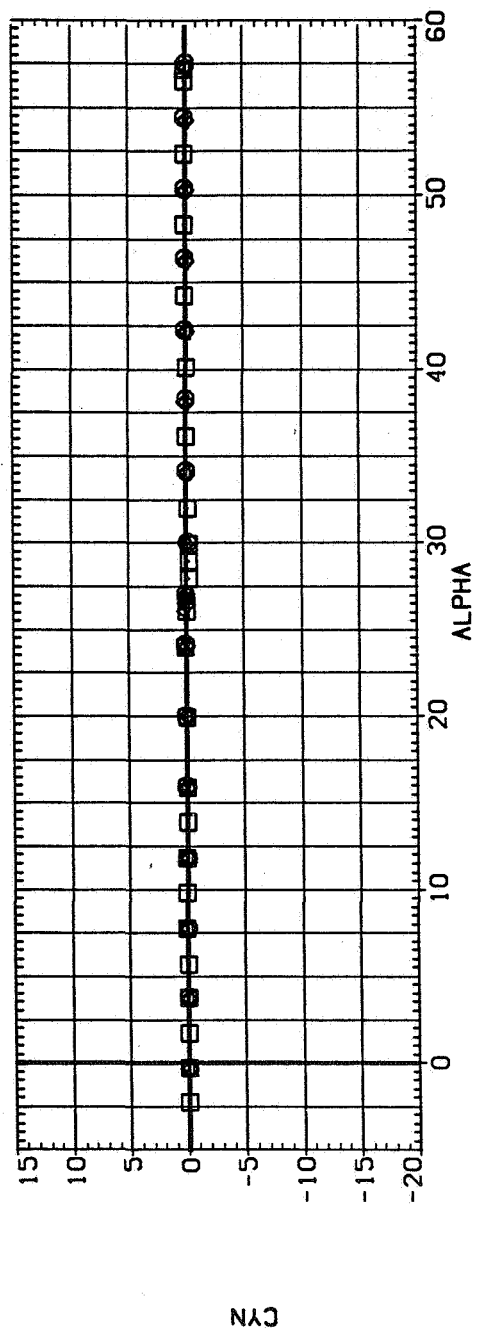
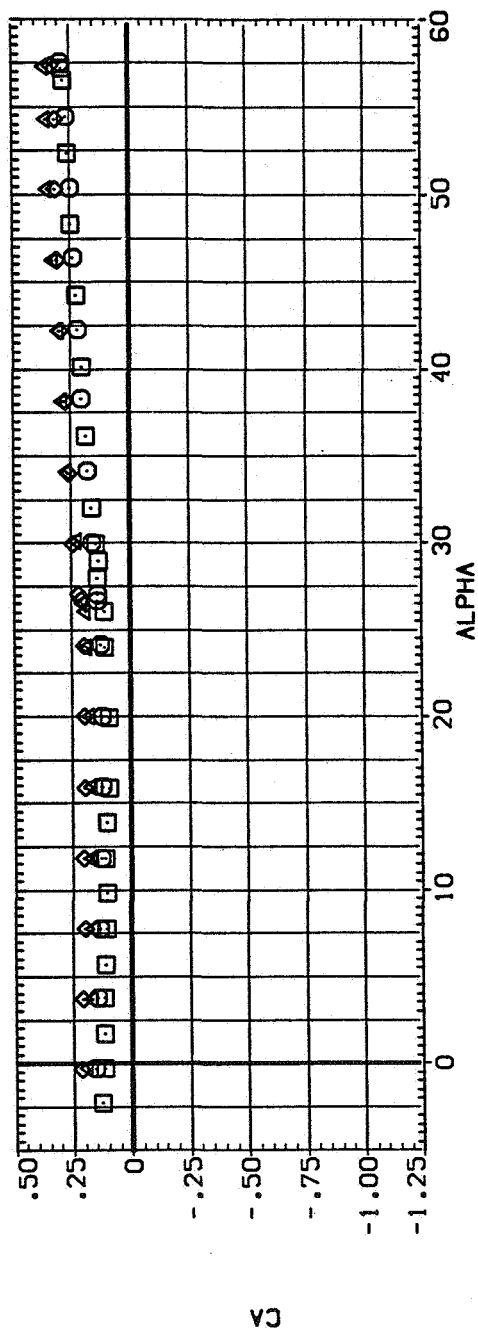
$\square$  N3 C1 S  
 $\square$  N3 C1 S  
 $\square$  N3 C1 S



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

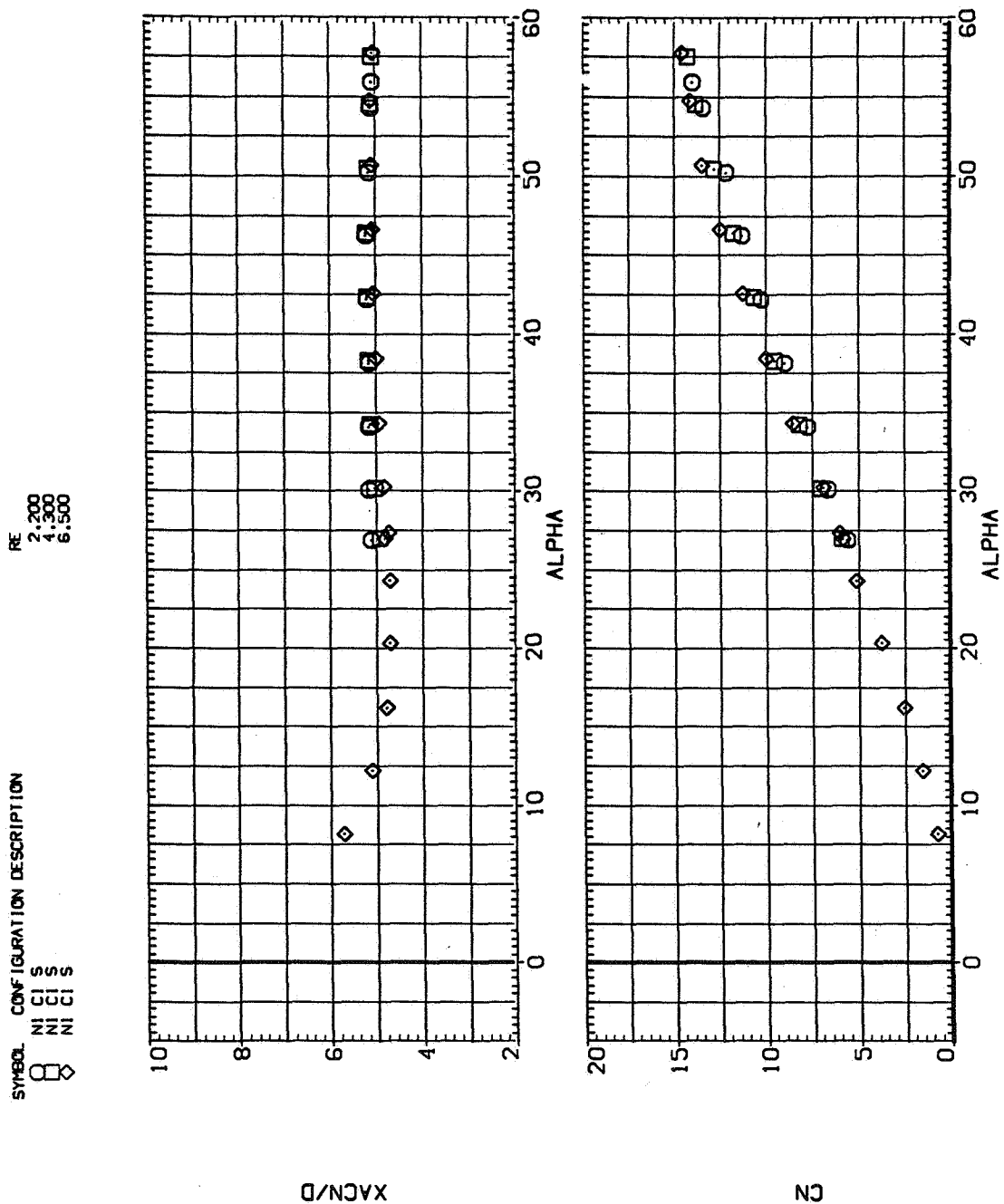
Figure 22.— Continued.

SYMBOL CONFIGURATION DESCRIPTION  
 ○ N<sub>3</sub> Cl S  
 □ N<sub>3</sub> Cl S  
 ⊗ N<sub>3</sub> Cl S



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 22.— Concluded.



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 23.— Effect of Reynolds number for  $N_1 C_1 S$ ;  $M = 0.6$ .

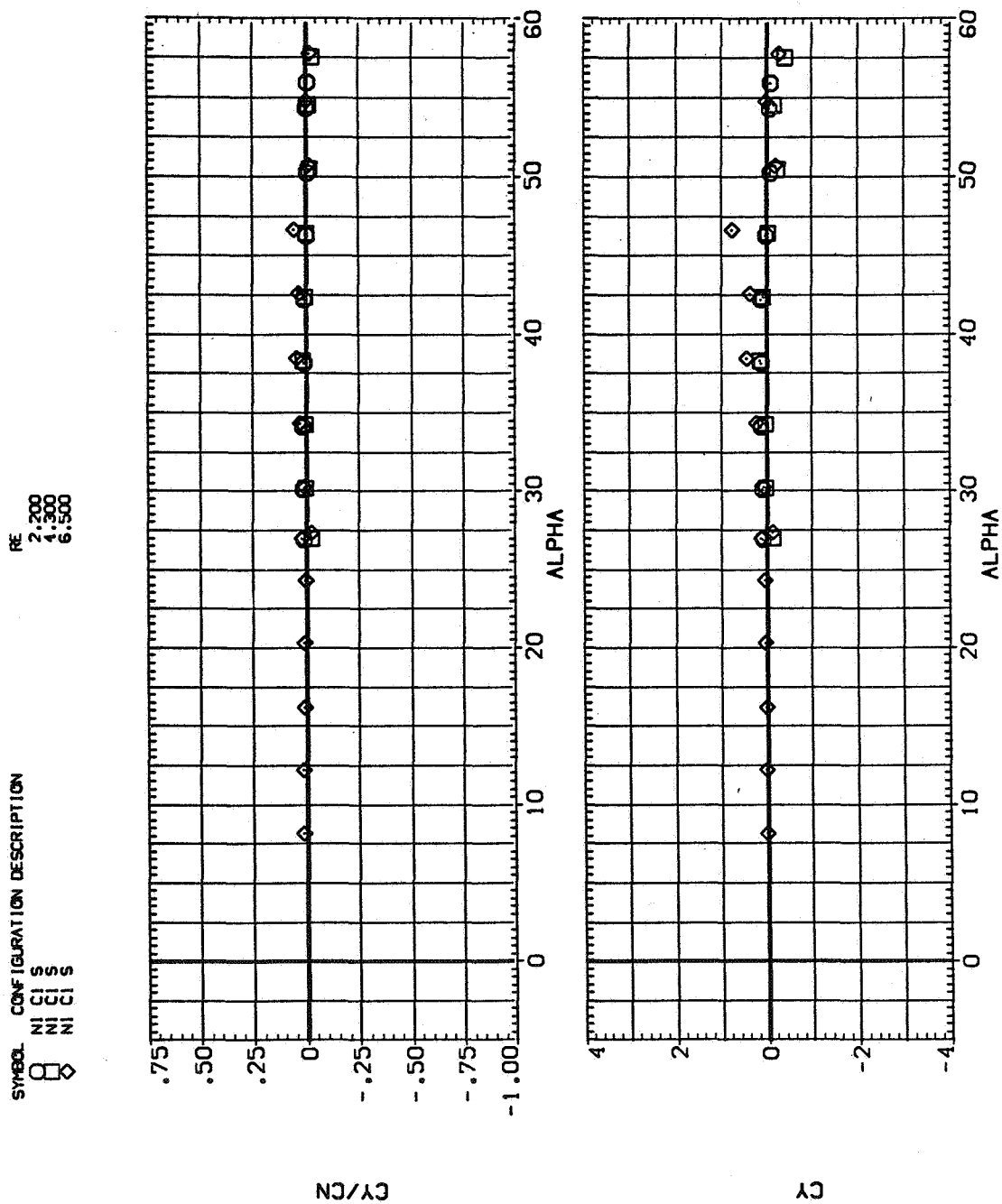
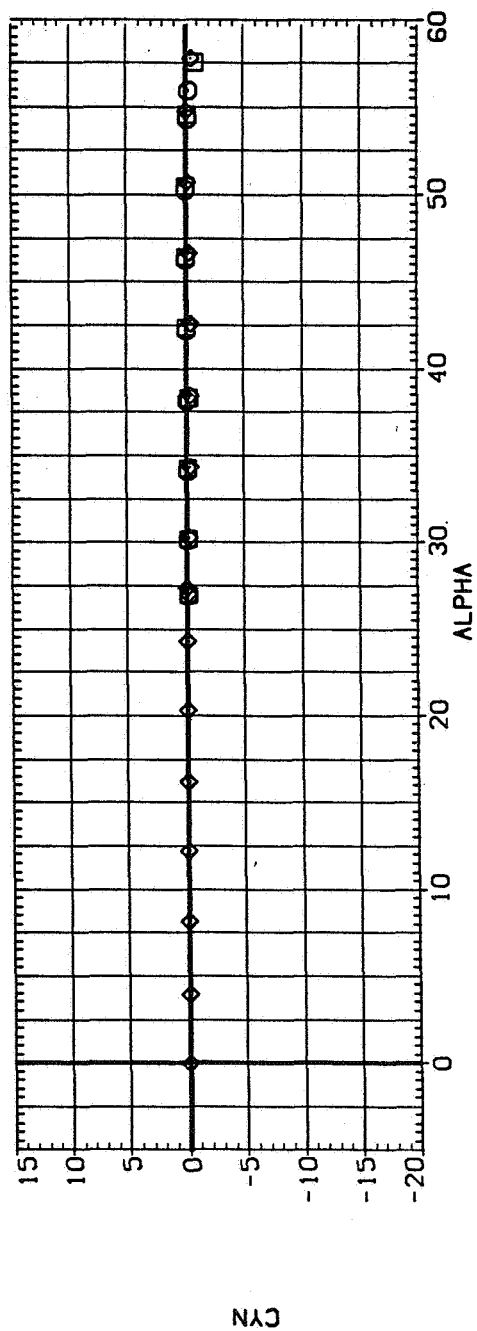
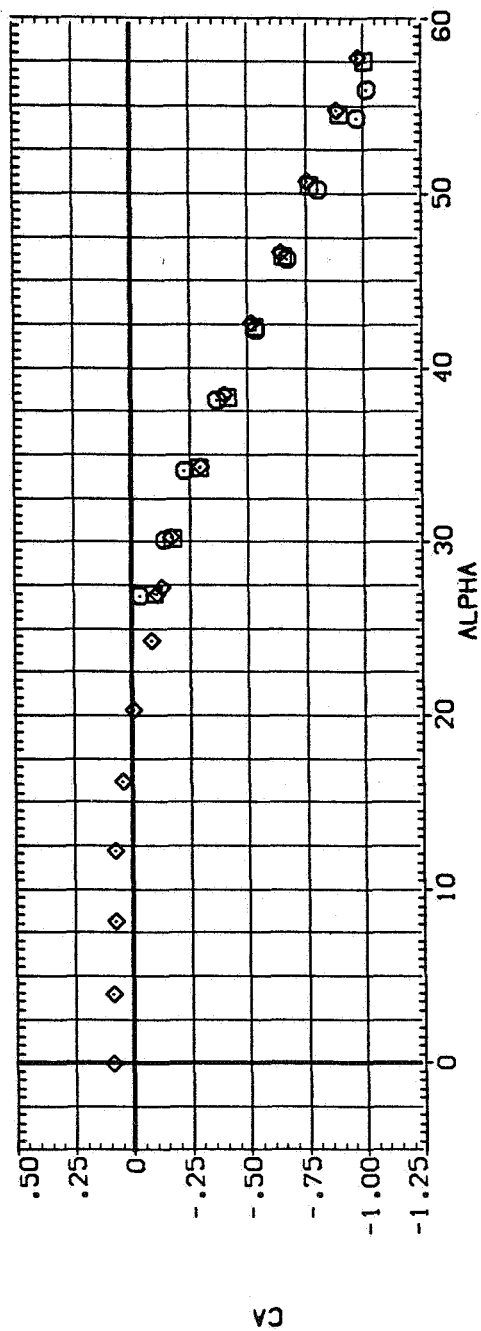
(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 23.— Continued.

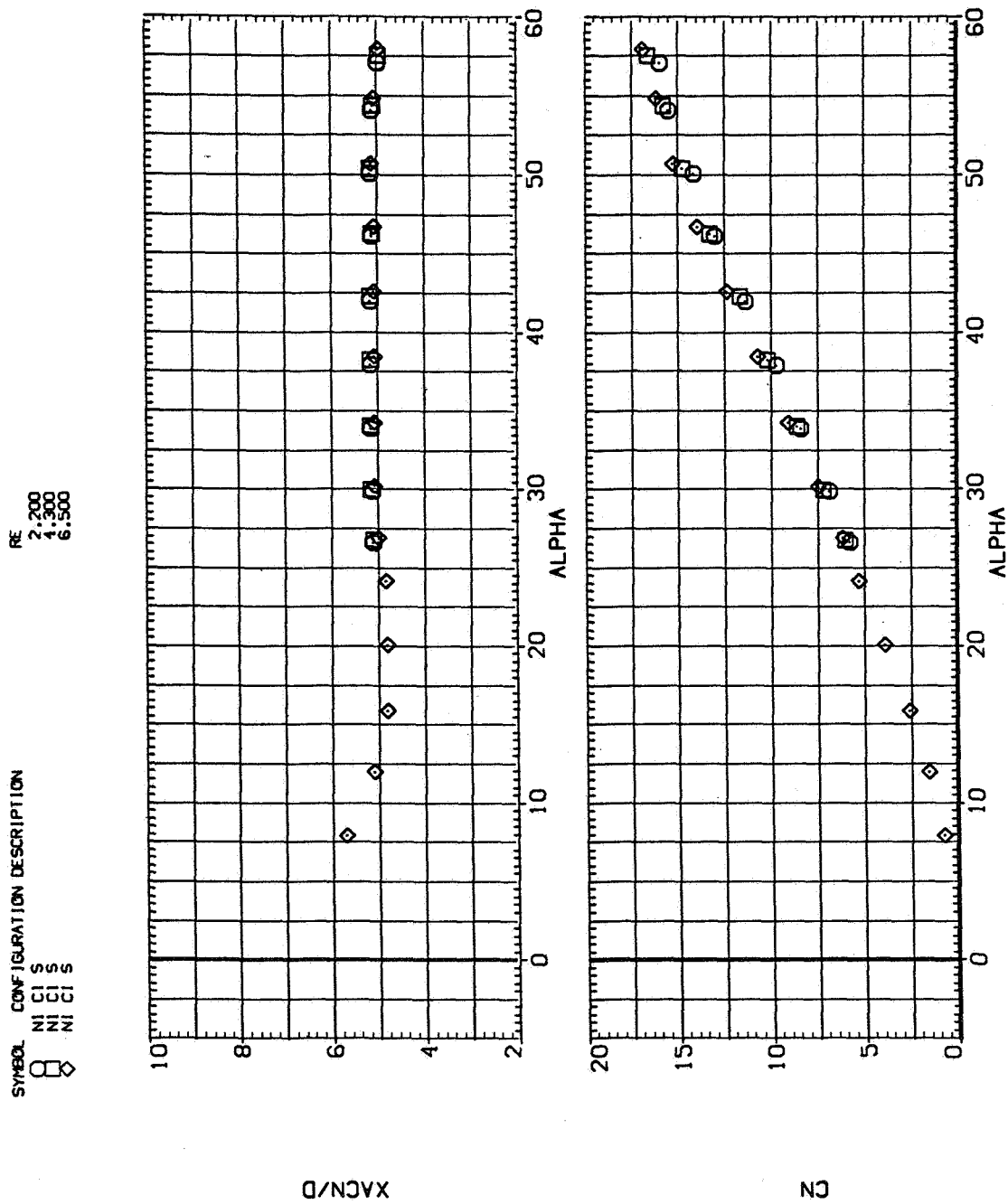


SYMBOL	CONFIGURATION DESCRIPTION	RE
NI	CI S	2.200
NI	CI S	4.300
NI	CI S	6.500



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 23.— Concluded.

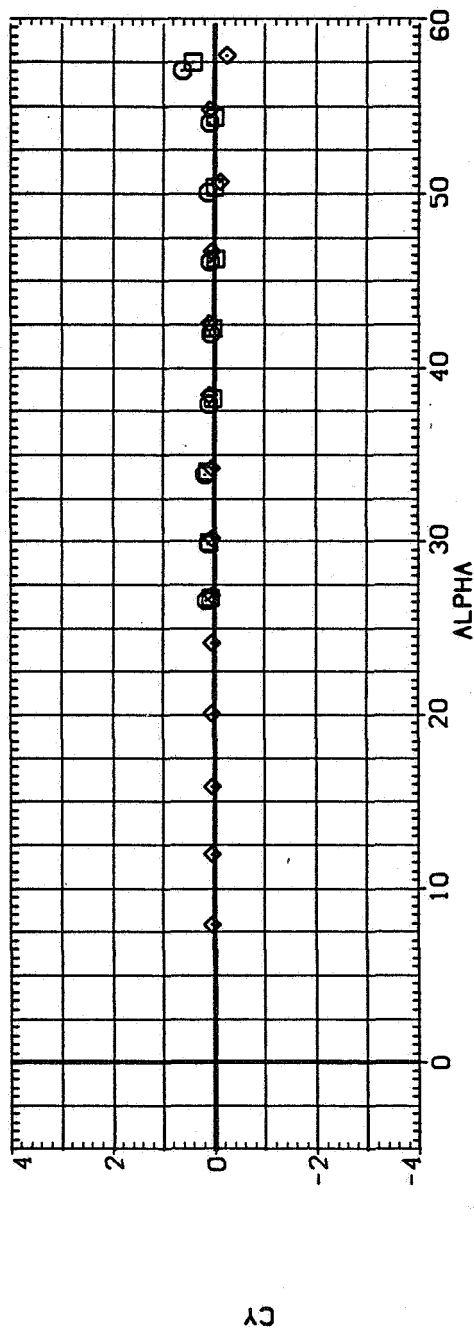
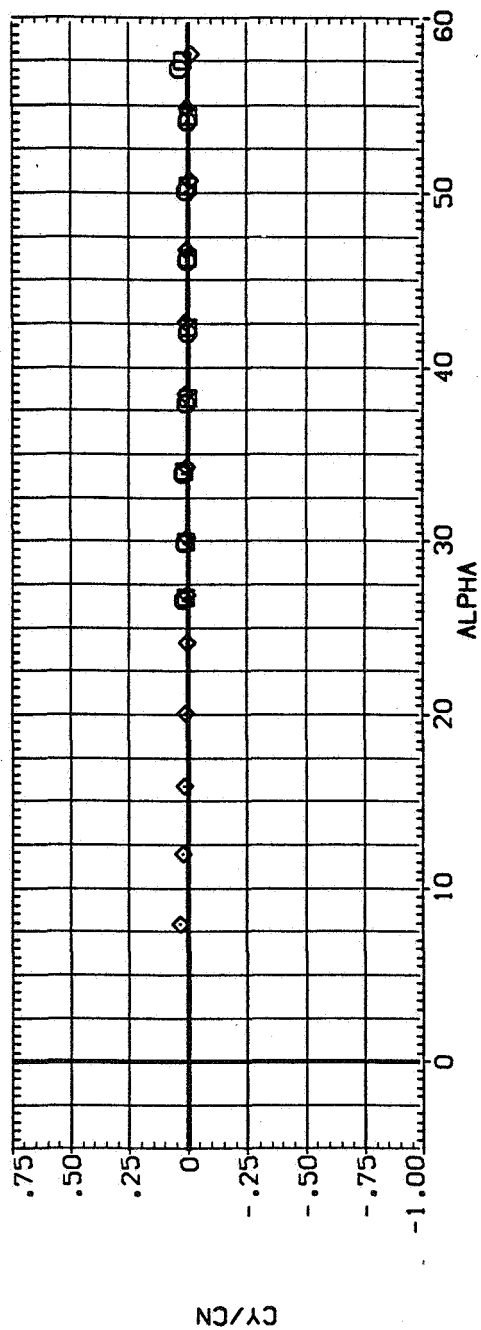


(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 24.— Effect of Reynolds number for  $N_1 C_1 S; M = 0.9$ .

RE  
2,200  
4,300  
6,500

SYMBOL CONFIGURATION DESCRIPTION  
NI CI S  
NI CI S  
NI CI S

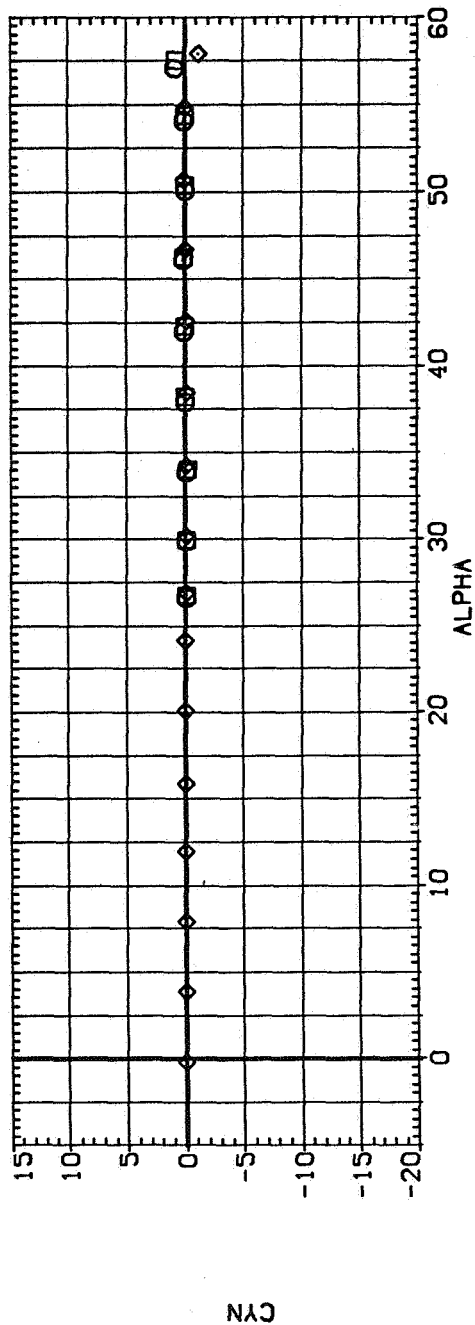
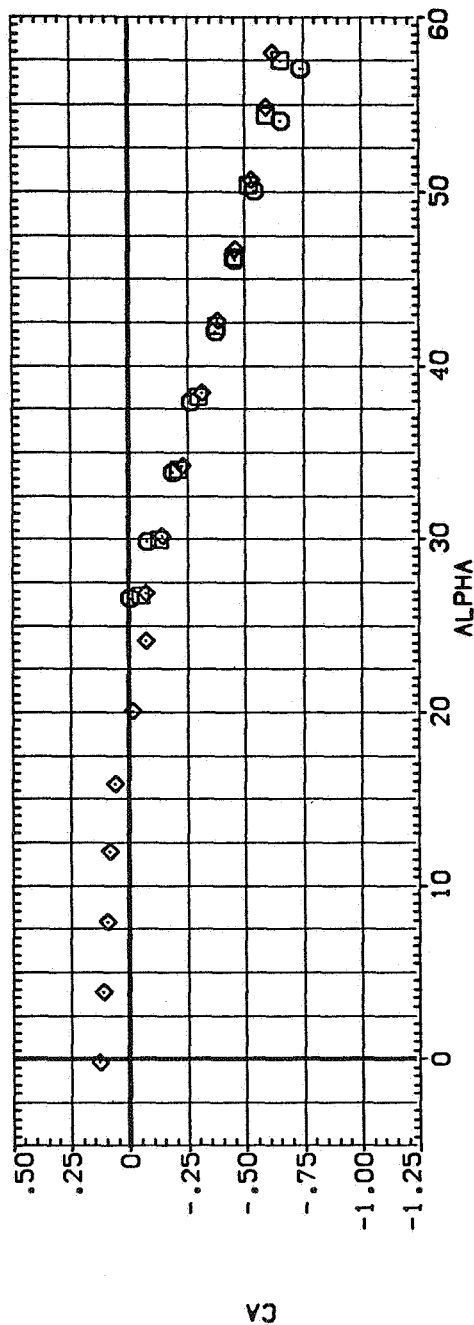


(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 24.— Continued.

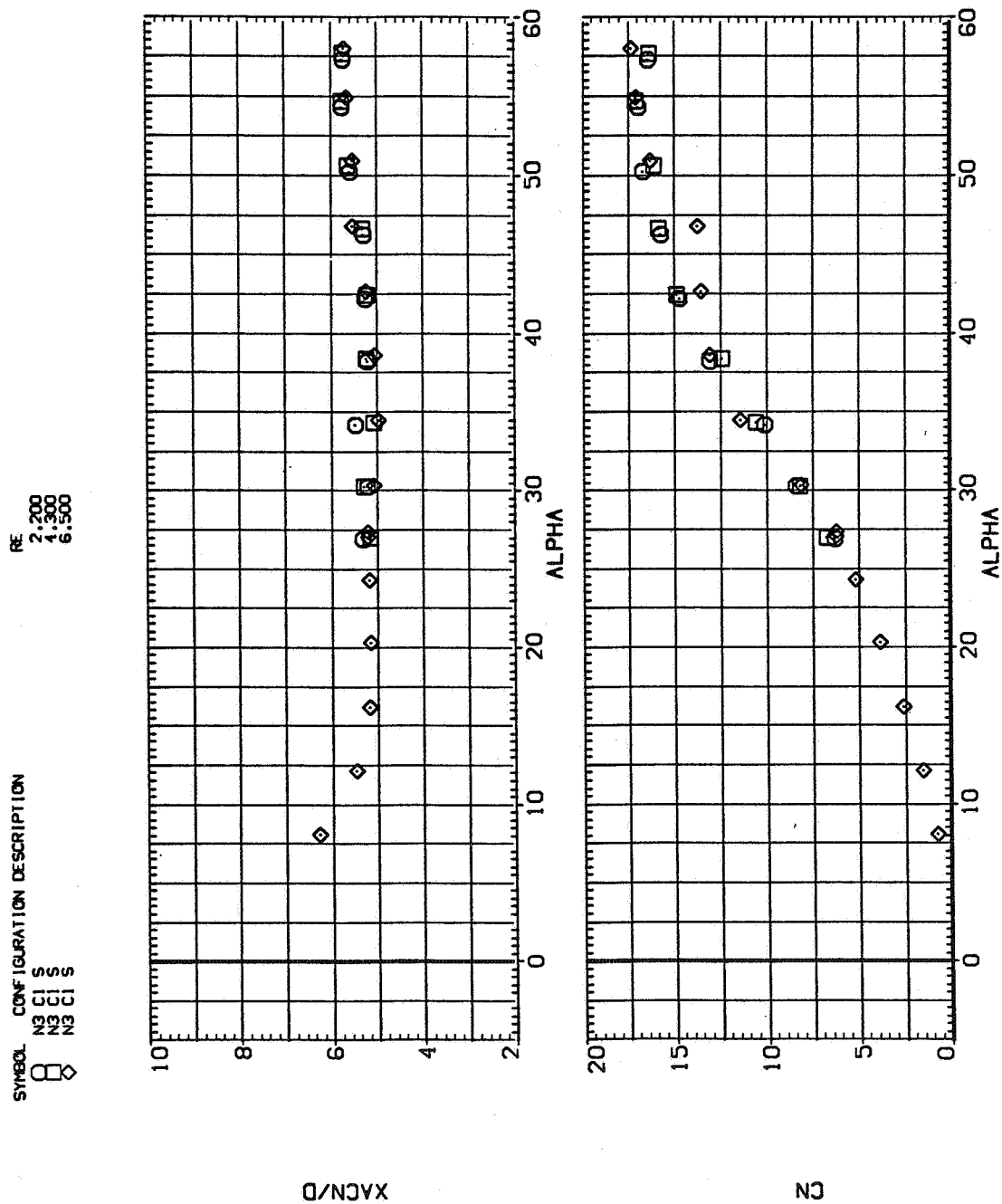
SYMBOL CONFIGURATION DESCRIPTION  
 NI C I S  
 NI C I S  
 NI C I S

RE 2.200  
 4.300  
 6.500



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 24.— Concluded.



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 25.— Effect of Reynolds number for  $N_3C_1S$ ;  $M = 0.6$ .

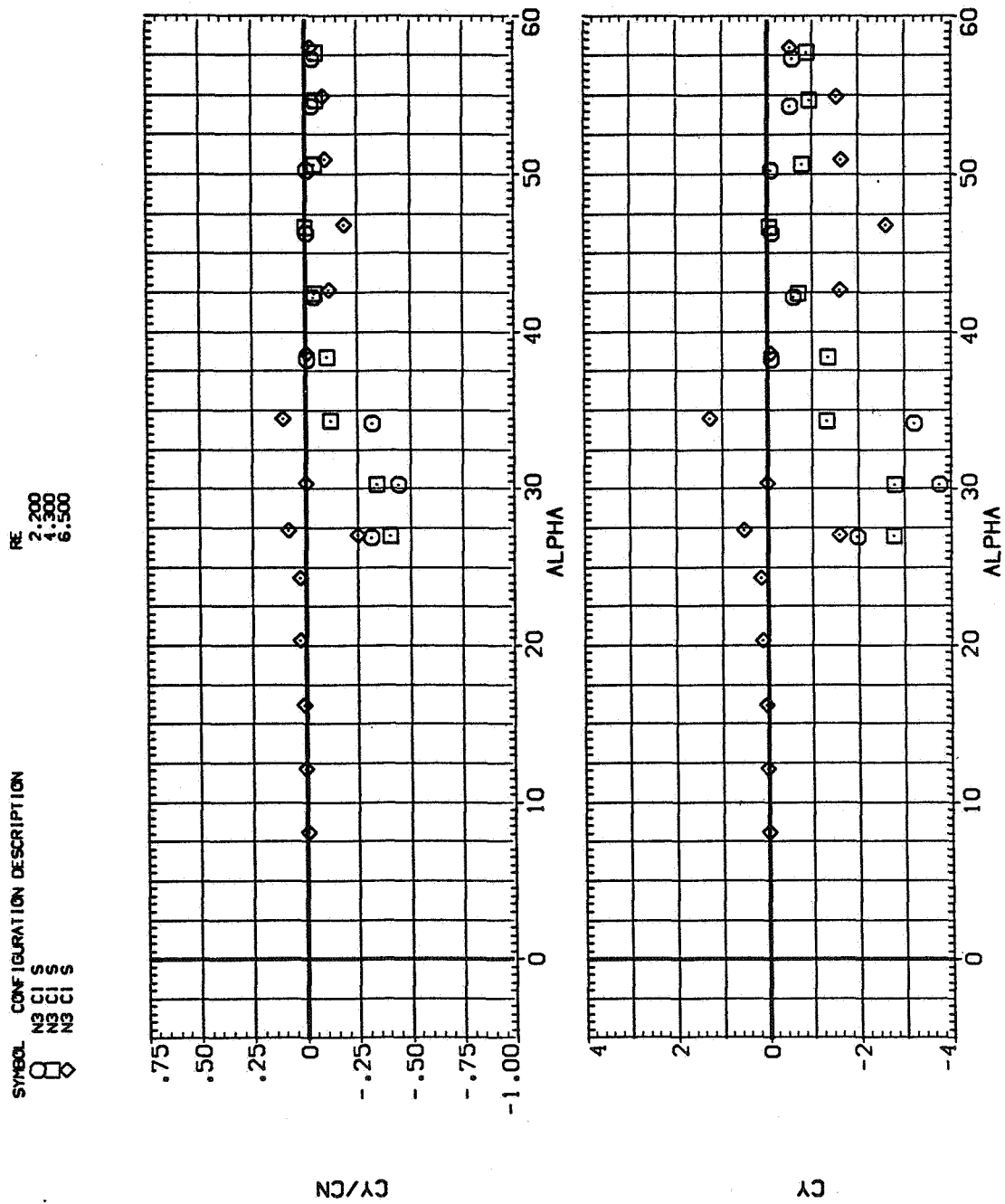
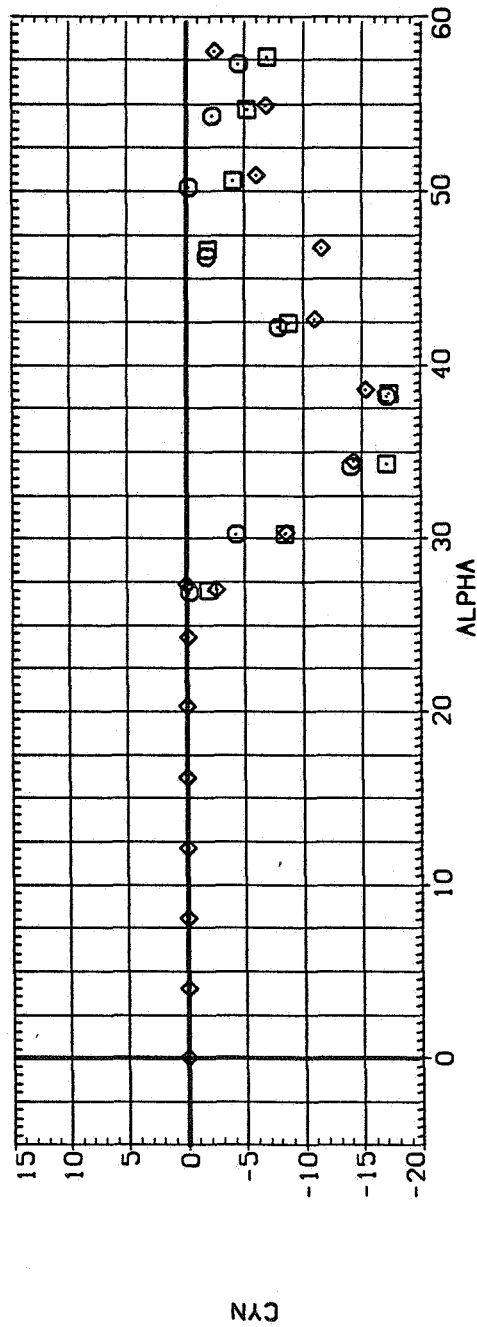
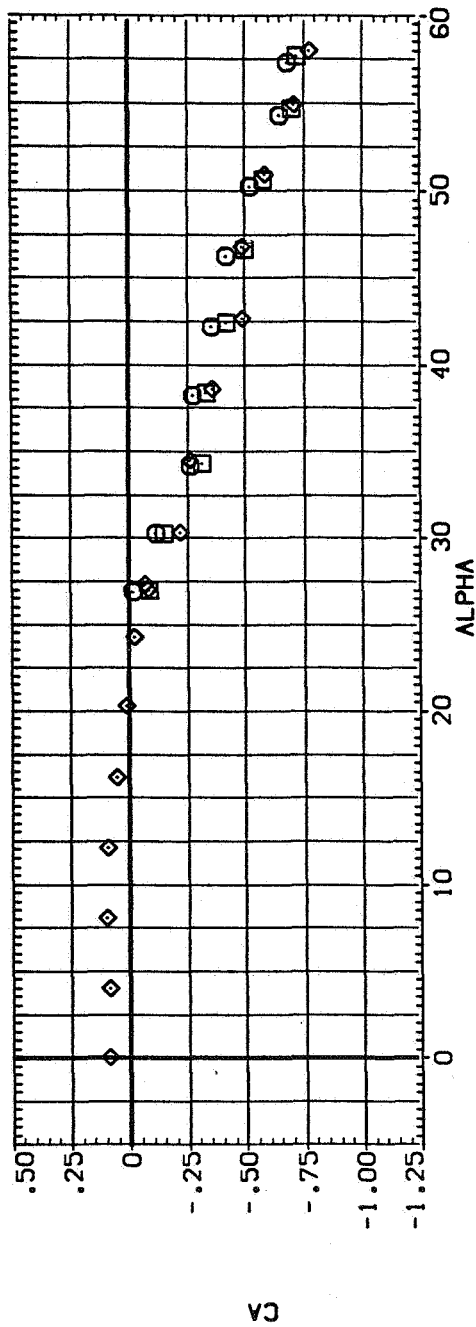
(b)  $CY/CN$  and  $CY$  versus  $\alpha$ .

Figure 25.— Continued.

SYMBOL CONFIGURATION DESCRIPTION

RE 2.200  
4.300  
6.500



(c)  $C_A$  and  $C_N$  versus  $\alpha$ .

Figure 25.— Concluded.

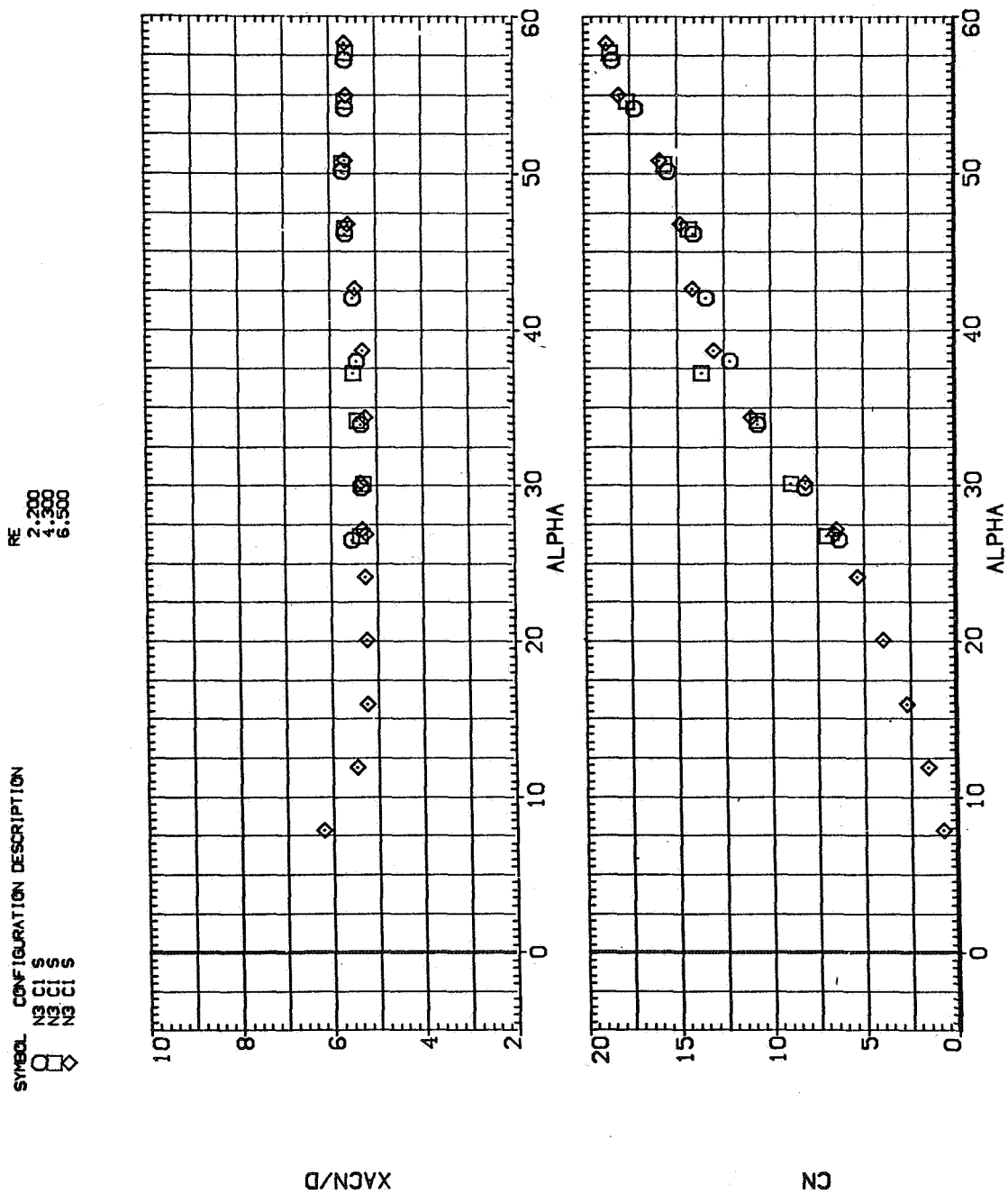
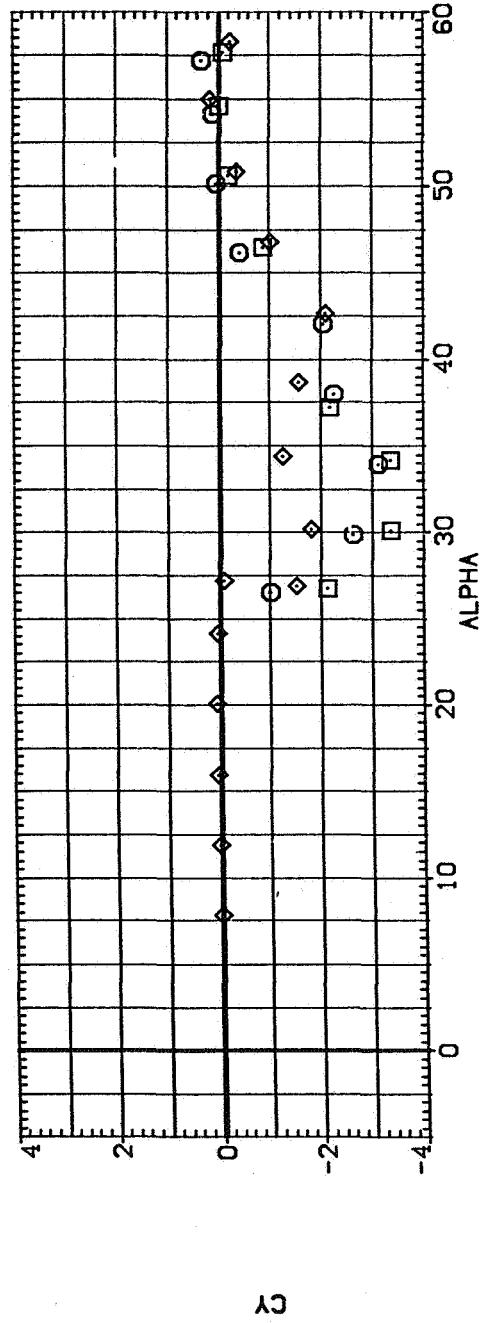
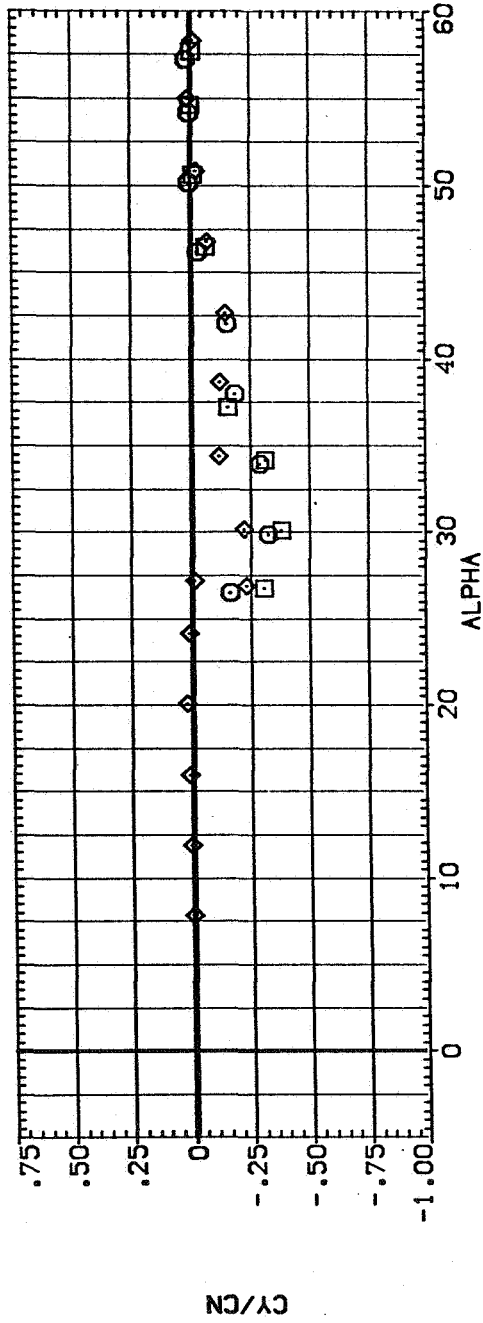


Figure 26.— Effect of Reynolds number for  $N_3 C_1 S$ ;  $M = 0.9$ .



SYMBOL CONFIGURATION DESCRIPTION

RE 2.200  
4.300  
6.500



(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 26. — Continued.

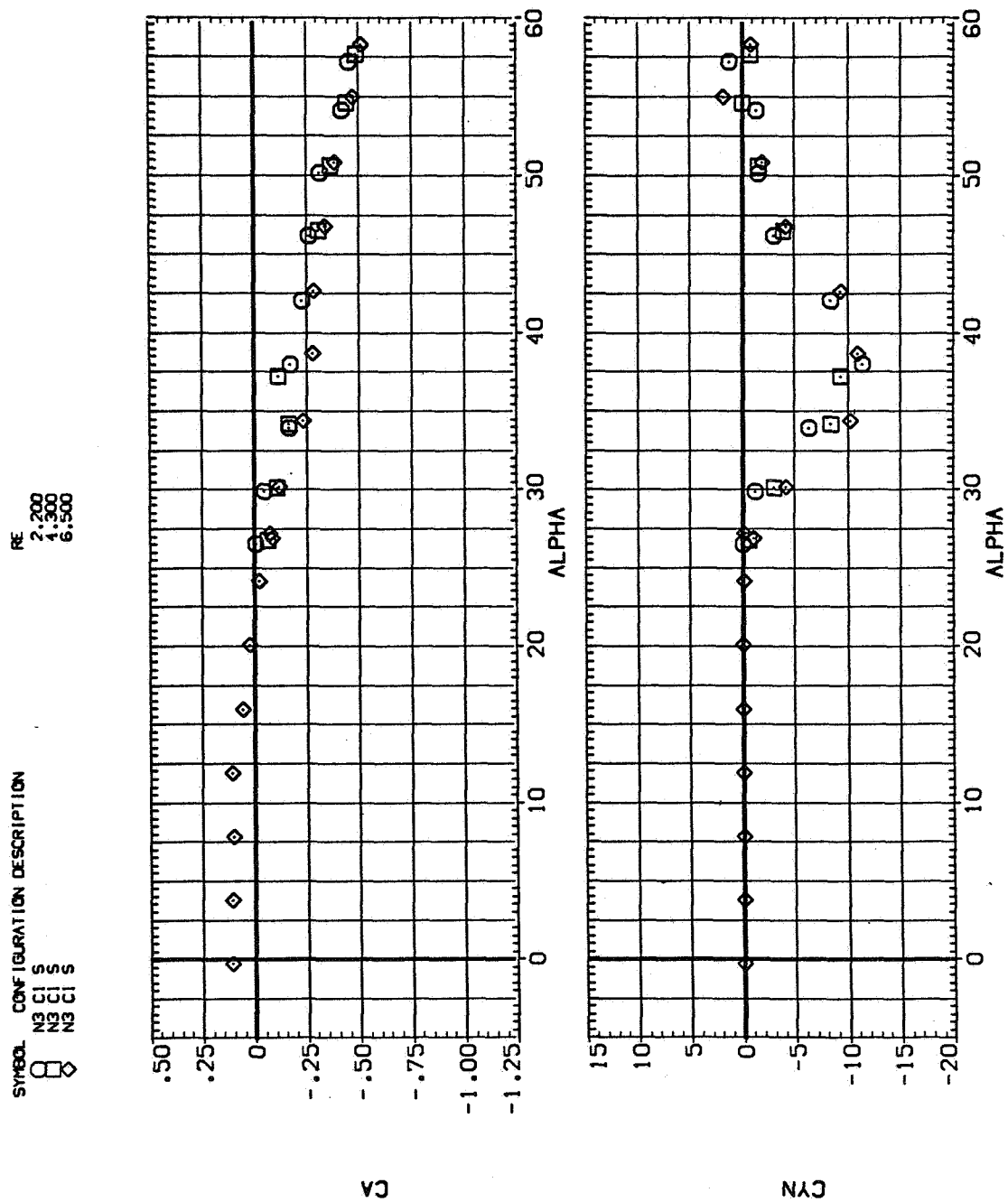
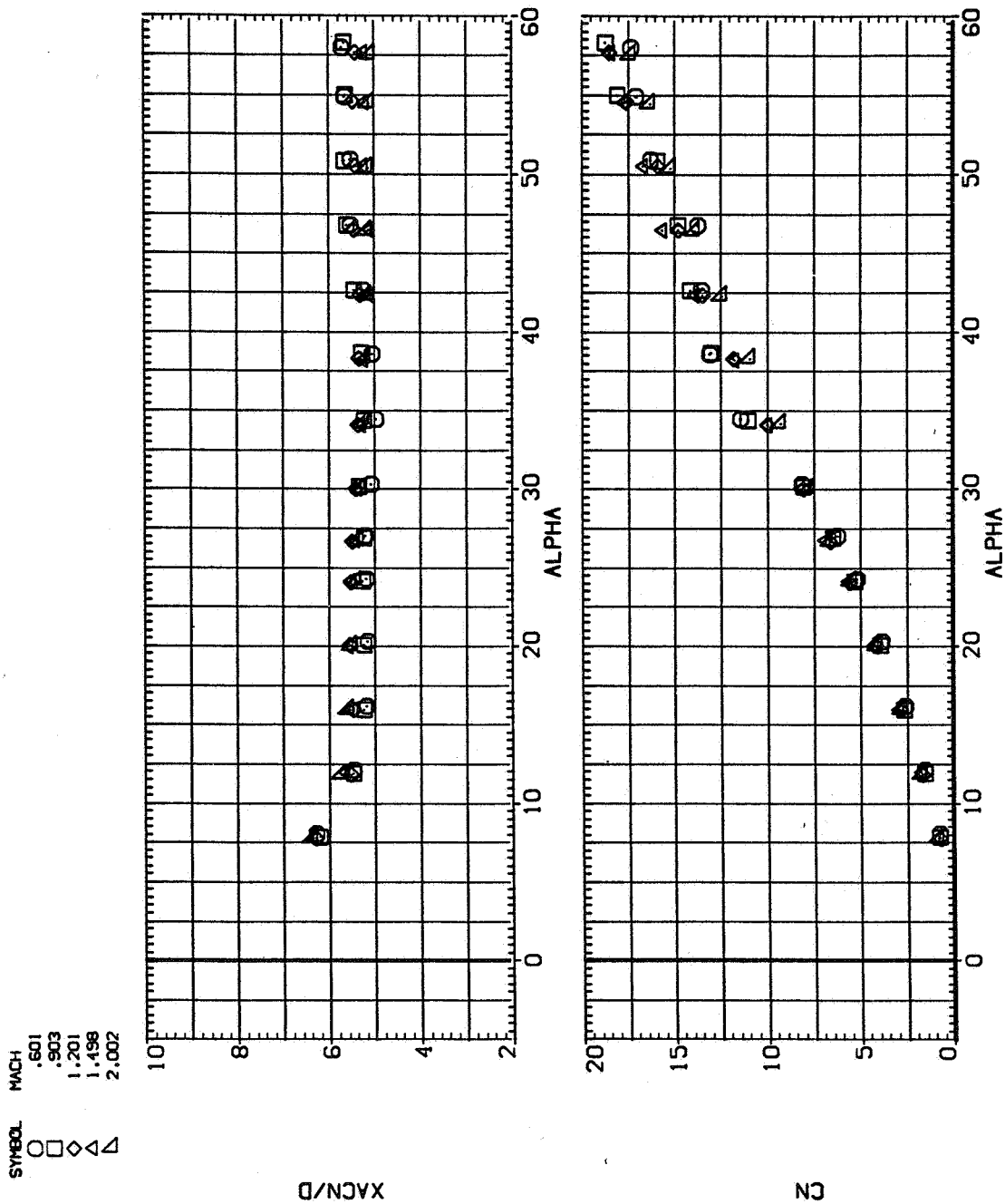
(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 26.— Concluded.



(a)  $x_{acN}/d$  and  $C_N$  versus  $\alpha$ .

Figure 27.— Effect of Mach number for  $N_3C_1S$ .

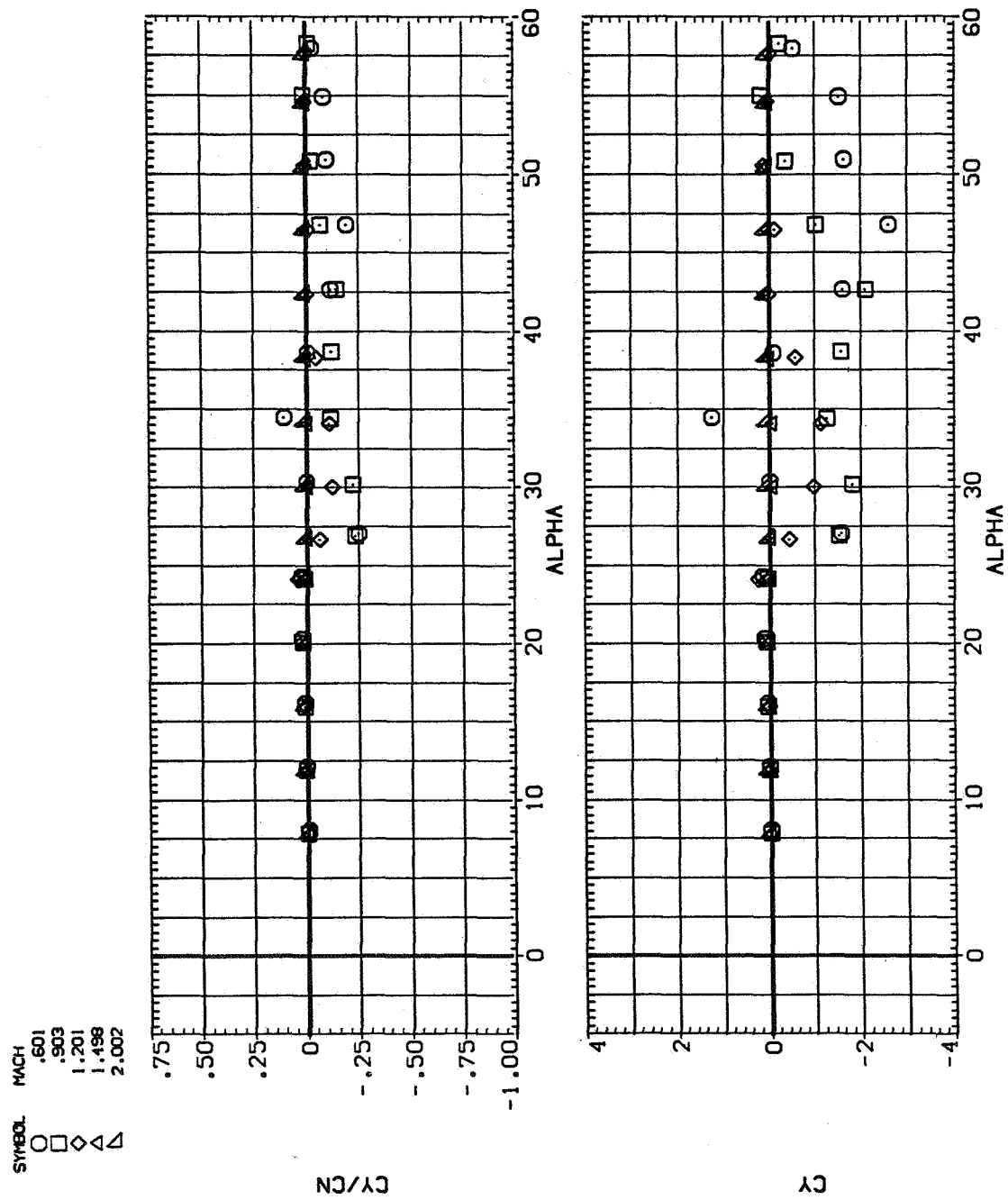
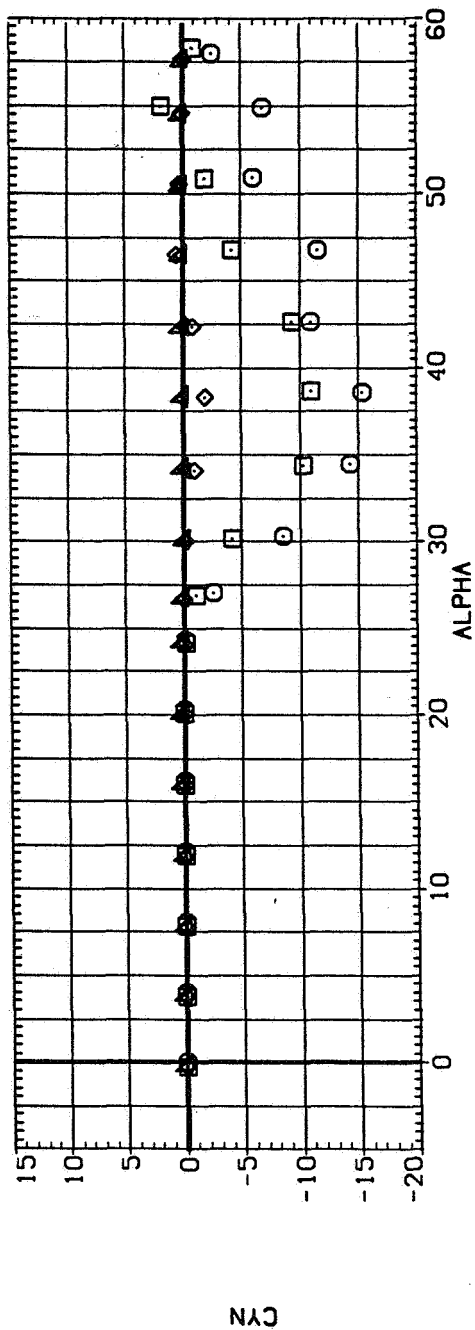
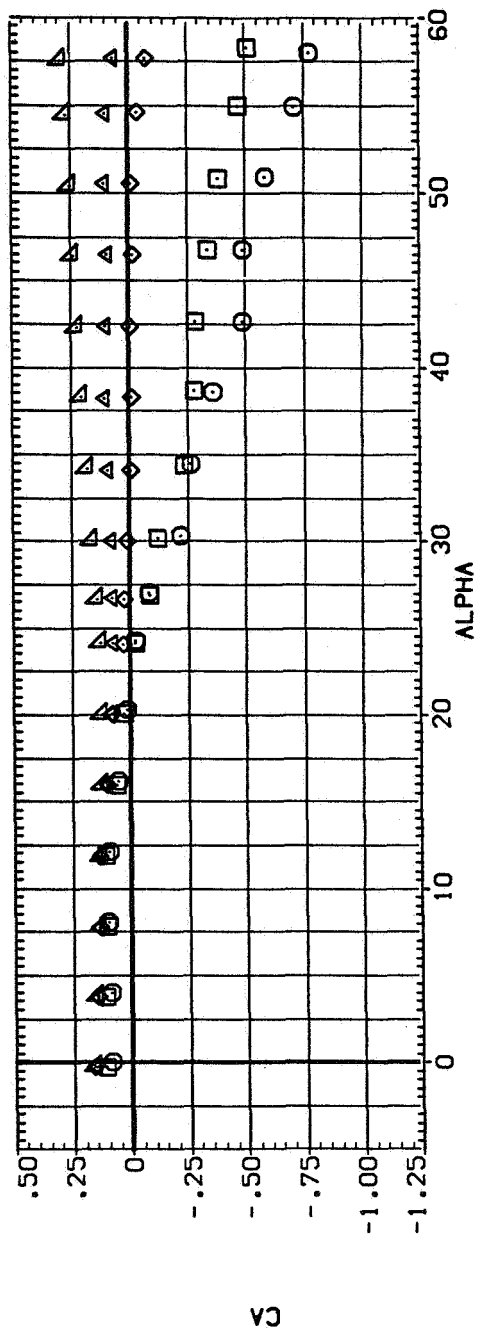
(b)  $C_Y/C_N$  and  $C_Y$  versus  $\alpha$ .

Figure 27.— Continued.

SYMBOL  
 MACH  
 .601  
 .903  
 1.201  
 1.498  
 2.002



(c)  $C_A$  and  $C_n$  versus  $\alpha$ .

Figure 27.— Concluded.



POSTMASTER: If Undeliverable (Section 158  
Postal Manual) Do Not Return

*"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."*

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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